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An Illustrated Weekly Journal.

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Sealed Tenders, endorsed "Electricity Department — Tender for Workshop Crane," must be delivered to me, at my Office, before Ten a.m., on Friday, 19th October, 1923.

The lowest or any Tender will not necessarily be accepted.

By Order,
W. J. BOARD,
Town Clerk.

Guildhall, Nottingham,
20th September, 1923. B 710

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The Company do not bind themselves to accept the lowest or any Tender.

F. C. McQUOWN,
Manager and Secretary,
County of London Electric Supply Co., Ltd.,
Moorgate Court, Moorgate Place, B.C. 2.
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The Directors do not bind themselves to accept the lowest or any Tender.

A charge, which will not be returned, will be made of 5s for each copy of Specification No. 1, and of 2s. 6d. for each copy of Specification No. 2.

Copies of the Drawings may be obtained at the Offices of Messrs. ROBERT WHITE & PARTNERS, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W. 1.

A. MUIRHEAD,
Managing Director.

91, Petty France, S.W. 1.
21st September, 1923 B 722

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A. MUIRHEAD,
Managing Director.

91, Petty France,
Westminster, S.W.1.
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REINFORCED CONCRETE BRIDGE ACROSS THE THAMES AT READING.

ON Wednesday next, the 3rd prox., a new bridge across the River Thames at Reading will be officially opened for traffic. It is of a particularly graceful design, and is notable for its low rise and for the span of the main arch, which is the largest of its type (180 ft.) in this country. The views and drawings of the bridge shown on the present and following pages, on page 400 and on Plate XXII, published with this week's issue of ENGINEERING, afford ample proof of the pleasing appearance of the structure. The bridge is constructed on the Hennebique system of reinforced concrete, the designers and engineers for the work having been Messrs. L. G. Mouchel and Partners, Limited, 38, Victoria-street, Westminster. The design, we understand, was selected in competition with others, and was adopted owing to coming within limits of headway and rise which could otherwise only be economically secured by means of a suspension type of structure. Construction was carried out by Messrs. Holloway Brothers (London), Limited, Westminster, and was completed under the supervision of Mr. D. J. B. Wilson, clerk of works. The drawings on Plate XXII show the actual proportions of the design, while Fig. 21, on page 400, is a reproduction of a photograph of the finished structure.

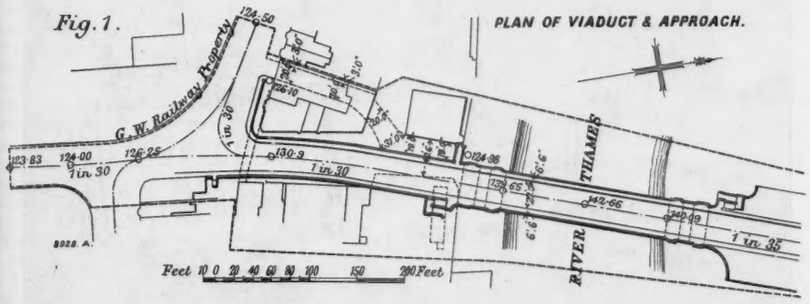
The site of the new bridge is an excellent one, within easy reach of the centre of the town and of the passenger stations and goods yards of the railways serving the area. Fig. 1 annexed shows the location, from which it will be seen that on the southern bank of the river the bridge is approached from three important roads. By way of West Forbury-road, Vastern-road and De Bohun-road traffic can pass from the bridge direct to the Market-place. On the north bank of the Thames the approach leads across meadows to Caversham by way of a new main road. As will be seen from Fig. 1 the construction of the bridge involved relatively little demolition. The land necessary for the approaches and abutments was secured at a reasonable figure, and good gradients were obtainable. On the southern bank the slope was fixed at 1 in 30, and on the northern at 1 in 35. On the former the approach is flanked by walls, that on the east side terminating at Macduff's Hotel, and that on the west swinging round at right angles, nearly opposite the hotel, and being continued for some distance along the street past some stores. The tow-path is on the south side of the Thames at Reading, and access to this is provided by stairways incorporated in the abutment on this bank. On the north bank the structure is terminated by splayed wing walls of comparatively short length, the approach being completed by a raised earth embankment with sloping sides not confined by walls. At the north abutment a stairway to normal ground level is also provided. These several features are all clearly shown in the general drawings, Figs. 3 to 20, on Plate XXII. The first of these shows the elevation of the main span and abutments; Fig. 4 shows the wall on the west side of the south approach, while at right angles to this, as described above, runs the short spur shown in Fig. 5. The wall on the east side is characterised by features similar to those shown in Fig. 4 for the west side wall.

The main span is, as stated, 180 ft., and the rise being only 18 ft., the bridge is of very graceful lines. It is to some extent marred on the south side of the arch by the unavoidable provision of the tow-path, but the whole design is so pleasing that this small blemish is fortunately not at all prominent. The southern approach rises on a series of arches of 19 ft. 6 in. span carried on piers standing on wide concrete bases; the lower portion of the approach is plain filling confined between walls finished with false arches and piers, the latter being centred 16 ft. apart. This spacing is continued for the piers in the spur wall. Immediately in the rear of each abutment is a single semi-circular archway of 12 ft. width.

The width of the bridge between parapets is 40 ft., thus providing a roadway of 27 ft. and two foot-paths of 6 ft. 6 in. As regards exterior finish little actual ornamentation has been included in the design, which is commendably simple, reliance for effect having been placed in the adoption of bold mouldings for the cornices, parapets, &c., and the treatment of the main piers. The parapets and abutments are of Portland stone, the other parts of the structure, including exterior work, being of reinforced concrete.

The general features of the construction of the main arch and abutments are shown in Figs. 6 and 8. The abutment foundations are mass concrete blocks about 50 ft. long by 45 ft. wide. Actually the underside of these blocks was modified from the form shown in Fig. 6 to the stepped form illustrated in Fig. 13. The bulk of the concrete in these blocks is of 1 : 11 : 3 : 6 quality, but at the inside upper edge taking the direct thrust of the arch concrete of 1 : 5 : 2 : 4 quality is used for a depth of about 9 ft. by 7 ft. across the block, strongly reinforced. Longitudinal reinforcing bars of 1 in. diameter at 12 in. centres are also embedded in the mass concrete blocks near the lower surface.

Fig. 1. PLAN OF VIADUCT & APPROACH.



The main span is formed of four main arch ribs supporting longitudinals which carry secondary beams and the decking. Four sets of horizontal braces are arranged between the main arch ribs. The arch ribs run out into the main longitudinals and decking as the middle of the arch is approached, but the portions of the span where they are widely separated are furnished with spandrel columns connecting the two. Details of the construction of the main span are shown to a larger scale in Figs. 9 to 12, Plate XXII. Of these Fig. 9 is one-half of one of the inside ribs. Two half cross-sections are given in Figs. 11 and 12, the former being taken about 30 ft. from the abutment, while the latter is taken at the centre. The main outside ribs are 48 in. wide and 56 in. deep at the springings. The depth reduces to 31 in. at the crown, as shown in Fig. 12. The two inner ribs are rather larger, being 54 in. wide and 42 in. deep at the crown. At the springings the depth is the same as for the outer ribs. The ribs are centred 12 ft. 9 in. apart. The spandrel columns are 10 in. by 24 in., except at the abutment, where the inside columns project 16 in. only from the vertical face of the 4½-in. cross-wall. The columns are centred 10 ft. apart longitudinally, the interior rows being placed centrally on the arch ribs, while those carried by the outer ribs are placed at the outer face of the latter. This is well shown in Fig. 11. The spandrel columns support the main longitudinals, which are 10 in. wide by 20 in. deep apart from the deck slab, which is 7½ in. thick. The secondary beams are shown clearly in Figs. 11 and 12, and as indicated in Fig. 10 are spaced at 5 ft. centres. They are 7 in. wide and of 14 in. depth below the decking. Where the longitudinals run out into the arch ribs the secondary beams extend direct, of course, between the latter, and thus form a very stiff structure. In the spandrel lengths of the arch, however, where the ribs do not benefit by the support, in a sideways direction, of the decking, braces, as mentioned above, have been introduced of a section of 14 in. by 14 in. The position of these is shown in Fig. 9. The reinforcing of the main ribs consists of 1¾ in. bars, the inside ribs having 14 bars both at the top and bottom, this number being increased to 18 at the crown. In the case of the outer ribs seven bars are used, top and bottom, near the haunches, increased to 18 top and bottom at the crown. The underside of all the arch ribs is lined off uniformly, the greater depth of the central ribs at the crown being accommodated by raising the central portion of the decking to the extent of 11 in. This will be clear from the sections given in Figs. 11 and 12. As shown in Fig. 9, the main bars of the reinforcement in the arch ribs are run out into, and anchored in, the mass concrete foundation. The outer ribs and longitudinals incorporate cornice mouldings and carry the stone parapets with open ballustrading. The system of shuttering adopted for the main span is shown in Fig. 2, on page 386, and Fig. 22, on page 400, which are reproductions of photographs taken during construction.

Dealing next with the approaches, on the southern side, for a distance of 142 ft. from Macduff's Hotel, the road is formed over ballast and chalk filling placed between reinforced concrete retaining walls. The latter are carried on mass concrete footings, from which reinforced uprights and counterforts are carried up at intervals, supporting thin wall panels, also of reinforced concrete. Beyond this section of fill, the approach takes the form, as indicated above, of a raised viaduct. Figs. 14 to 20 give details of this. The viaduct consists of a series of spans on piers centred 19 ft. 6 in. apart. It is slightly curved, but the main components are of uniform design. The spans are carried on piers placed three in a row across the bridge. Fig. 15 shows a half cross-section, and the arrangement of the main beams connecting the columns or piers which, above the base have a section of 1 ft. 6 in. by 3 ft. 6 in., in a longitudinal direction. These columns are centred 20 ft. 7½ in. apart across the bridge. The main beams are 12 in. wide by 3 ft. 6 in. deep and the main reinforcement consists of three 1½ in. bars and three 1⅜ in. bars, additional bars being inserted in the lower part of the beam under the pipe channels. At the piers the beams are increased in depth by some 9 in.

The longitudinals consist of two exterior arched beams and of seven straight beams. An elevation of the side arched beams is given in Figs. 16. The main arc is struck at a radius of 14 ft., running out into the piers through arcs struck at 2 ft. radius. A section of these beams at the crown is given in Fig. 19, the reinforcement consisting of three main bars above and four below, the cornice having a further two bars embedded in it. In addition to the usual stirrups extending between upper and lower bars, bent transverse reinforcing ¼ in. bars are inserted at 8-in. intervals in these beams (see Fig. 16). The seven inside longitudinals of each bay are of three types, the three in the centre being uniform, and the two outer most being of heavier section and reinforcement as shown in Figs. 15 and 18. These beams are 12 in. wide, compared with 8 in. for those further inside, and the reinforcement consists of six bottom bars and three top bars, as against four bottom bars only for the other beams. Longitudinal details are given of typical beams in Figs. 17 and 18 in which the spans to the left show beams which run out into the retaining cross wall at lower end of the viaduct, beyond which the road is carried on filling. The spans to the right represent the type of beam used for the remainder of the viaduct except at the extreme northern end, where modification was again necessitated on nearing the piers and arch of which details are given in Fig. 13. The whole of this end of the approach is based upon the large mass concrete foundations which take the thrust of the main span. As shown in Fig. 13, these consist of monoliths measuring 50 ft. 6 in. in the

longitudinal direction, and extending to a depth of about 26 ft. below ground level, this being actually rather greater than was anticipated from trial borings. At this end of the viaduct the bays between the piers are filled in with side walls, and the viaduct ends in a cross wall, 9 in. thick in its lower portion and 7 in. thick above, stiffened by four verticals 1 ft. by 2 ft. 1 in. and 2 ft. 3 in., reinforced with 1⅛-in. and 1¼-in. bars, and an intermediate horizontal of 10 in. by 1 ft. 11 in. section, as shown in Fig. 13, reinforced by 1¼ in. bars. The base of this cross-wall is a reinforced toe, 2 ft. 3 in. wide and 12 in. thick, formed integral with the mass concrete foundation. This wall takes the thrust of the semi-circular archway, which has a thickness of 7 in. and is reinforced with ⅜-in. bars. On the opposite side this arch is supported by low buttresses shown in Fig. 13. The buttresses are 8 in. wide, and the reinforcing bars are 1 in. and 1¼ in. in diameter. They run down into the mass concrete of the foundation. In line with the top of the buttresses is an horizontal beam 10 in. deep by 1 ft. 11 in., corresponding to the stiffener on the other side of the arch already referred to.

The side panels on either side of the 12-ft. archway are 9 in. thick for the lower portion and 6 in. thick above, reinforced with vertical and horizontal ⅜-in. bars inside and out.

On the north side of the river the main span, as already indicated, terminates in a manner similar to that adopted on the southern side, and the main mass concrete foundation carries a 12-ft. archway flanked by piers and panel walls. Beyond this the roadway runs out between curved wing walls in the form of a gradually falling embankment. There is nothing particularly noteworthy about this end of the bridge from the structural point of view. The wings are carried on mass concrete which is wide close to the bridge and gradually narrows down as the height decreases. On the west side incorporated in the wing wall structure is a stairway leading to ground level and giving access to an area which is to be laid out by the Corporation as a promenade. This obviates the need for counterforts or buttresses at this point, but the further extension of the wall is provided with two small counterforts. The eastern wing is supported by five counterforts of a height and bottom width varying with the position in the wall. These features are indicated in Figs. 6, 7 and 8 already referred to.

The bridge was designed for the standard rolling loads laid down by the Ministry of Transport, resulting in a total load of this class of 293 tons, on the roadway, with a superload of 112 lb. per square foot on the footpaths.

REINFORCED CONCRETE BRIDGE ACROSS THE THAMES.

MESSRS. L. G. MOUCHEL AND PARTNERS, LIMITED, ENGINEERS, WESTMINSTER.

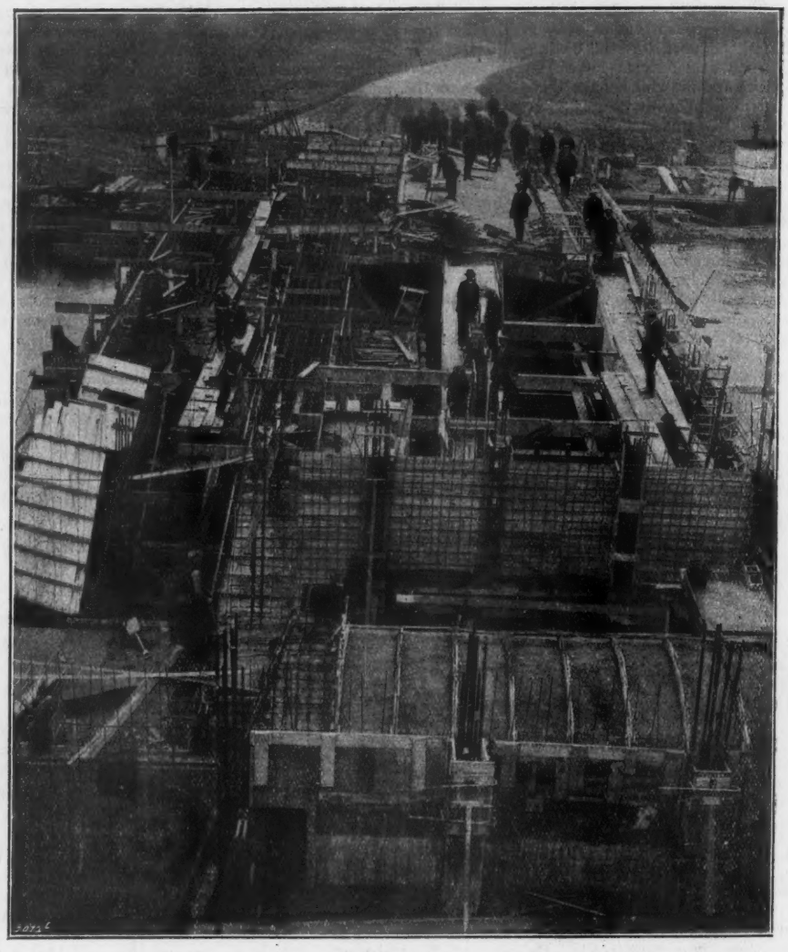


FIG. 2. VIEW, FROM SOUTH BANK, OF MAIN SPAN DURING CONSTRUCTION.

THE BRITISH ASSOCIATION.

SECTION G.—ENGINEERING.

(*Continued from page* 362.)

CONSERVATION OF WATER RESOURCES.

WHEN the members of the section reassembled on the morning of Monday, the 17th inst., Sir Henry Fowler again taking the chair, the first paper read was one by Mr. J. Parry, on the "Conservation and Control of Water Resources." This paper we shall reprint in a later issue, but we should now explain that it deals mainly with the need for more effective control of the appropriation and distribution of the sources of water supply in this country. The sources of supply covered by the paper were the upland catchment areas, supplies direct from rivers, and underground supplies, and the water, the author pointed out, was required for town supplies, rural supplies or in connection with hydro-electric power schemes. He dealt with the principles upon which the allocation of the sources should be based, and explained the distinction to be drawn between survey and administration. The recommendations of the Water Power Resources Committee were reviewed, the objections to them pointed out and alternatives suggested. Finally, the desirability of an inquiry into the matter by a Royal Commission was urged.

The discussion was opened by Professor F. C. Lea, who said that there was no question of greater importance than that raised by the author. Every large industrial area, the speaker stated, had commenced in the neighbourhood of what was originally an adequate water supply, but as the area developed it had become necessary to go farther afield for the supply of water. There was thus a danger of large and wealthy cities obtaining monopolies of the best sources to the detriment of the rural areas. In connection with the Elan Valley scheme for the supply of Birmingham, the rainfall in the catchment area was known, the quantity of compensation water was known, as also, of course, was the quantity of water supplied to Birmingham; but it was also important to know the actual quantity of water which found its way into the reservoirs and the quantity which ran to waste. Steps were being taken to determine this in connection with the Birmingham supply. It was most important to control supplies when discovered and to know the quantity of water available. The speaker agreed that the appointment of a Royal Commission was the best means of obtaining a solution to existing difficulties, and in connection with the Royal Commission he thought the Department of Scientific and Industrial Research, or some other body, would have to inquire into the quantities available.

Mr. Robert L. Sackett, who attended the meeting as a member of the American Association for the Advancement of Science, said Americans looked to Great Britain for guidance in connection with legal processes, some of which had been adopted with satisfactory results. This was true with regard to river-pollution legislation, and the formation of the Metropolitan Water Board to control the water supply of London had led to the formation of similar bodies in connection with the water supplies in Boston and New York. He hoped that we should be able to solve the difficult problem of equity in utilising water resources so that British methods could be copied in America in this respect also. In the United States, the speaker concluded, the great responsibility of engineers was not only to decide upon and carry out work for present requirements, but also to convince the political authorities of the necessity for looking ahead for thirty or fifty years.

Mr. J. S. Wilson, who also spoke on this paper, said the two points he wished to refer to were the energy to be derived from the water and the provision of local reservoirs for distribution. If local reservoirs could be provided, the head of the water could be used for power production, but usually opportunities for constructing large reservoirs locally could not be obtained easily. The principal cause of the trouble was the over-growth of large cities and towns, and it was necessary either to prevent towns from growing larger or to go beyond the geographical areas of those towns for a supply of water.

No other member wishing to take part in the discussion, the chairman called upon the author to reply, which he did briefly, saying that he had been

greatly interested in Mr. Sackett's remarks. The difficulties of the American water engineer were very great, but one of the causes of his difficulties was his willingness to take water from a polluted source and to rely upon the efficiency of filtration processes rather than to take steps to ensure the purity of the original supply.

WIRELESS TELEGRAPHY IN THE MERCANTILE MARINE.

The next paper on the programme was one by Captain J. A. Slee dealing with the recent developments in the application of wireless telegraphy to the mercantile marine. This paper, which we reprint on page 410 of this issue, was then read in abstract by the author. The discussion on the paper was opened by Professor G. W. O. Howe, who said he wished to call attention to the return, in connection with the wireless beam station at Inchkeith, to the laboratory experiments of Hertz. The latter, he said, had used short waves only a few metres in length, had tried to reflect them by means of a parabolic reflector, and had used transmitting apparatus very similar to that employed at Inchkeith. As wireless telegraphy had developed, long waves, up to 20,000 m. or more in length, had been employed, but in recent years the tendency had been to return to the short waves of Hertz. The author had referred to certain areas in the English Channel in which bearings obtained by the ordinary methods of wireless direction-finding were unreliable, and the speaker said he supposed it would only be necessary to erect a few new stations to cover these. He thought the time would come when a ship in narrow waters would be able to navigate in perfect confidence in foggy weather. The speaker also referred to the importance of high-speed working in connection with wireless telegraphy on ships.

The next speaker, Professor E. W. Marchant, referred to the advantage possessed by the heterodyne method of receiving continuous-wave telegraphy in connection with the elimination of atmospherics. With regard to the short-wave stations of the type set up at Inchkeith, the speaker pointed out that these had a very important advantage over lighthouses in that the transmission was not effected by fog. He also mentioned that in Mr. Franklin's paper describing the system, read before the Institution of Electrical Engineers, it had been stated that the range was increased by placing the receiver as high as possible above the ground, and inquired if this was being done in connection with the wireless-beam stations. With regard to the ordinary method of direction-finding, the speaker said he believed this was done on a wave-length of 600 m., and inquired how the errors experienced in this work compared with those obtained with the short waves used in the wireless beam. He thought the errors due to variable causes would be less with the short waves, but that the effect of the ground, and of ships situated between the transmitting and receiving stations, would probably be worse.

After Dr. J. S. Owens had inquired whether the patchiness of fogs had any effect in direction-finding work, the chairman called upon the author to reply. Captain Slee then said, in reply to Professor Howe, that the construction of stations, known as beacon stations, to cover the localities in which ordinary direction-finding was difficult had been under consideration for some time, but had not yet made much progress. Beacon stations, he said, should be placed at specially selected spots, such as at lighthouses or in light ships, but these stations would have to be unwatched and automatic in working. The United States authorities were ahead of us in this respect and had already installed four direction-finding stations in the approaches to New York Harbour. Most direction-finding work, he added, was carried out by the ship's telegraphist, which was necessary on account of the large amount of ordinary telegraphic work conducted on the same wave-length. With the short-wave system, however, there was no question of interference, and the navigating officers of the ship could use the apparatus themselves. To the question as to the wave-length used in ordinary direction-finding, the author said that the range from 400 m. to 1,000 m. was satisfactory, and he also stated that experience had proved that the weather conditions had no effect whatever upon the results obtained. It was, of course, important that the direction-finding aerials should be fitted in such a manner that they could not be blown out of position in a gale, but the transmission and reception of signals was independent of all weather conditions with respect to both accuracy and range.

SINGLE-BUCKET EXCAVATORS.

Captain Slee's paper was followed by one entitled "The Development of the Single-Bucket Excavator," read by Mr. W. Barnes. This paper, which we propose to reprint in a later issue, illustrated and described the development of single-bucket excavating machines from one designed in 1839 by W. Otis, of Boston, U.S.A., to the latest form of modern machines mounted on self-laying tracks. Both the navvy and drag-line types of machine were dealt with, as well as machines convertible for use as navvies, drag-line excavators, or grab-bucket excavators. Examples of machines at work under widely varying conditions were illustrated by a series of lantern slides, and their uses were further illustrated by means of a kinematograph film.

A brief discussion ensued in which a speaker inquired the cost of excavating ordinary material, and another speaker inquired if the machines had been used for excavating peat. Mr. Sackett also described the McMyler machine used in the United States for unloading ore, coal and limestone from the holds of ships. This machine, he said, enabled the ships to be unloaded as rapidly as they could be loaded, and thus greatly decreased the total cost of transport.

In his reply, the author stated that the cost of excavating easy material varied greatly, depending on the output, size of machine used, and other factors; it might be anything between 3*d.* and 1*s.* 6*d.* per cubic yard. He thought a machine of the endless chain bucket type had been used for excavating peat in Scotland, but could give no details of the work. He had seen the McMyler unloading machine at work at Duluth, and regarded it as extremely interesting, but he hardly thought it was included in the scope of his paper.

SMOKE ABATEMENT.

The next paper taken was one by Mr. J. B. C. Kershaw entitled "Smoke Abatement and the New Bill." In it the author first summarised the provisions of the Bill introduced into the House of Lords this year for the purpose of consolidating and strengthening the law relating to the emission of black smoke by works and factories, and then discussed the educational and voluntary methods which have been found most useful in combating the evils arising from industrial smoke. He described the work of the Verein für Rauchbekampfung of Hamburg, a voluntary organisation of steam users, and gave figures to show the development of this body. He concluded with a plea for the wider application in this country of similar voluntary methods for improving the efficiency of combustion and reducing the smoke nuisance.

The paper was discussed by two speakers, the first of whom, Dr. J. S. Owens, pointed out that it was necessary to educate the public to the desire to do away with smoke and then to devise means by which the desired result could be achieved. At present, he said, manufacturers had no desire to co-operate in the reduction of the smoke nuisance since they gained nothing by doing so. The economy resulting from the reduction of smoke, was very small; moreover, the smoke produced by any particular factory chimney did the owner no harm. In connection with the prevention of smoke, it would be necessary to devise some means for measuring it, in order to be able to define the permissible amount. If these two fundamental considerations could be settled, he thought the problem would be solved. He did not think manufacturers needed education in connection with smoke prevention as they already possessed the necessary knowledge, and it was certainly possible to work any industrial furnace without producing smoke. In conclusion, he gave the results of tests, made at the same time, of the air in London and in Liverpool, stating that the suspended particles in the air of the Metropolis had numbered 817 per cubic centimetre, while the corresponding figure for Liverpool was 1,200 particles per cubic centimetre.

The other speaker, Professor W. H. Watkinson, said he thought much of the atmospheric pollution of Liverpool arose from the smoke from the ferry steamers which was discharged at a much lower level than was that emitted by factory chimneys. He also expressed the view that magistrates needed education to induce them to impose the penalties provided by the existing law.

The author, on being invited to reply, said he had nothing to say, as he was in agreement with both the speakers, but he added the suggestion that Professor Watkinson should use his influence to have re-started the classes on smoke prevention held in Liverpool some years ago.

INVESTIGATIONS ON WATER TURBINES.

Dr. Hubert Mawson, then read his paper on the subject of water turbines, which formed the next item on the programme. The first part of the paper, which we shall reprint in a later issue, deals with an analytical method of predicting the form of the characteristic laws for a water turbine, the experimental investigation of these laws, and their application to design work and to the prediction of the laws for similar turbines. The second part of the paper gives analytical methods of estimating the rise of pressure in the pipe lines and the rise of speed of the turbine when the load is removed and the motion of the controlling vanes is known. The results are checked by experiments using a timing device consisting of a vibrating tuning fork and pendulum-controlled pens to obtain the variations in the above-mentioned quantities after the load is removed.

The first speaker in the discussion on this paper was Professor F. C. Lea, who, after congratulating the author on his work, said the latter was of great importance in connection with the future development of large hydraulic turbines. The only method of perfecting large turbines, he said, was to construct and test small models and apply the principles of dynamic similarity to the design of the large machines. Mr. R. L. Sackett and Professor W. H. Watkinson also expressed appreciation of the work described in the paper. In his reply, the author, after thanking the speakers, said the whole object of the work was the prediction of the output from large turbines. He had not been able to find the law governing the brake horse-power, but felt sure that such a law existed. It was only in connection with the prediction of brake horse-power that any discrepancies had been found, and he thought these discrepancies might be due to the holes formed in the rotor for the purpose of balancing end thrust.

THE STRENGTH OF FORKED CONNECTING RODS.

The last paper taken was one by Mr. W. J. Kearton, and this described analytical and experimental investigations carried out by the author on the strength of forked connecting rods. Two types of connecting rod were referred to, one having the gudgeon pin attached to the crosshead and the other having the pin integral with the fork. Both are forms of statically-indeterminate structures, and the author points out that the formulæ for calculating the stresses in the fork given in text books are based on erroneous assumptions. He fully explains a method he has devised for calculating the stresses in a connecting rod of the form in which the gudgeon pin is integral with the fork, and also gives an account of experiments made to verify the calculations. We intend to reprint this paper, in full, in a later issue.

But little time was available for the discussion of the paper, but Professor C. H. Bulleid asked if the author thought it sufficiently accurate to apply the ordinary beam theory to a curved beam of small radius. Professor W. Mason said he was afraid the paper would not provide much useful data for designers who required a formula which could be applied to all forked connecting rods of similar form. He also pointed out that on sections which were not perpendicular to the axis of thrust, there would be shearing stresses, and he inquired how these affected the results. Professor G. G. Stoney congratulated the author on his work, but said he had not had time to study it carefully, and Professor F. C. Lea pointed out that the author's equations were the same as those for an arch. Mr. Kearton then replied, but stated that the time available was insufficient for him to deal adequately with the points referred to by

the speakers. He agreed with Professor Bulleid, that the small radius of curvature of the fork would have an important influence on the stresses, but said he had not investigated the matter, his object having been to prove that the ordinary text book theory was inaccurate. The difficulty of supplying a formula for designers' use was that connecting rods were not of standard form, and any change in dimensions would affect the bending moments produced. It was quite correct that the equations given were those for an arch, but assumptions had to be made, and they might be wrong.

This completed the programme for the morning session, and the meeting then adjourned. In the afternoon the members visited the works of Messrs. British Insulated and Helsby Cables, Limited, at Prescot.

The Teaching of Dynamics.

On Tuesday morning, the 18th inst., the engineering section met with Section L. (Educational Science) for a joint discussion on the subject of the teaching of dynamics. The chair was occupied by Professor T. P. Nunn, the president of Section L., who after welcoming the members of the engineering section, called upon Professor Sir J. B. Henderson, D.Sc., to introduce the subject by reading his paper on the "Stroud System of Teaching Dynamics." This paper we reproduce, in full, on page 409 of this issue, so that we need not refer here to the nature of its contents.

The discussion was opened by Professor E. H. Neville, the greater part of whose remarks had reference to the necessity for forming a clear conception of the meanings of the arithmetical operations of division and multiplication. He also objected to the use of the word "rate" in the sense in which it was employed in the paper, remarking that this would lead to difficulties in the teaching of the calculus. Professor A. Barr, the next speaker, expressed strong approval of the Stroud system and disagreed with the previous speaker in his criticism of the use of the word "rate." Professor J. Thomson he said, had first called attention to the difference between rate and ratio, and there had been much discussion on the matter. The difficulty referred to by Professor Neville could be got over by not speaking of division and using the word "rate" instead. The speaker's own experience with the Stroud system confirmed all that Professor Henderson had said of it. There had always been difficulties with respect to the units in dynamical calculations, and, to avoid these, Professor Stroud, at a British Association meeting some thirty years ago, had introduced a system of naming rates and ratios by a particular word. The letter *a* was used to indicate multiplication and the letter *o* (over) to indicate division, a product such as feet × seconds being expressed as "*f a s*," and a quantity such as feet per second as "*f o s*." By cancelling out the letters in a complicated expression the units in which the answer was given could be seen at once. The speaker gave a few examples of the use of the system and expressed regret that the paper referred to had been neglected.

Mr. A. E. Heath, who followed, said the first impression given by the paper was that the Stroud system was a mere trick of symbolism, but that in itself was an excellent thing. He doubted, however, whether it would entirely remove the difficulties in the matter of units. Professor F. C. Lea said he regarded the system as something more than symbolism, as it led to greater accuracy, which was of the utmost importance to engineers. As an example of the effects of the confusion of units, he mentioned that some second year engineering students asked to calculate the cost of stopping an Atlantic liner had given answers ranging from a few pence to over 1,000,000*l*. The question of dimensions, he added, was also of great importance to engineering students, and this was brought out very clearly in Professor Henderson's paper. Another speaker, whose name did not transpire, said the whole difficulty as to units in dynamical calculations would vanish if the metric system were employed throughout.

The chairman then explained that the time available for discussion had elapsed, and in calling on Sir Henry Fowler to give his views, remarked that he had been extremely interested in the paper, but thought it would be difficult to persuade teachers to adopt the system. Sir Henry then said that engineers would welcome any system which would prevent mistakes in calculations, but he hoped it would not involve the learning of a new language. He also remarked that closer co-operation between educationalists and engineers was desirable. Professor Henderson, who was then called upon by the chairman to reply, did so very briefly. The use of the term "rate," he said, had been objected to, but it occurred in everyday life in questions of barter when money was multiplied by goods. The Stroud system acknowledged this and wrote it down.

Complex Stress Distribution.

The engineering section then returned to its own meeting place to consider the report of the Committee on Complex Stress Distributions in Engineering Materials, but, before the report was dealt with, Mr. Thomas M. Newell, chief engineer of the Mersey Docks and Harbour Board, gave a short general description of the Gladstone Dock system, which the members were to visit in the afternoon.

The Complex Stress report includes six papers, three of which were read by their respective authors, while an additional communication by Professor E. G. Coker, the chairman of the committee, was read by Mr. J. S. Wilson. This communication compared various experimental methods of determining the stress at a point in a plate by optical and mechanical methods. The first paper of the report was one dealing with the calculation of the stresses in pipes reinforced by steel rings shrunk on at intervals, the additional strength due to the rings permitting pipes of large diameter to be employed without involving the use of excessively thick welds. This paper, which we shall reprint in a later issue, was read by its author, Professor G. Cook.

Following this, a joint paper by Mr. J. S. Wilson and Professor B. P. Haigh, on the stresses in bridges, was read in abstract by Mr. Wilson. This paper we commence to reprint on page 411 of this issue, so that we need not refer to it further here. The third paper read was by Professor W. Mason, on the distribution of stress in round bars under alternating torsion and bending. In this paper, the distribution of stress is studied with the object of finding a relation between stresses in hollow and solid specimens. The author states that alternating torsion or bending of round bars leads to a condition in which the range of strain, at a given range of torque or bending, increases to a stationary value, provided that such given range is less than the fatigue range and greater than the primitive elastic-limit range. For mild steel in this stationary condition of strain, the following assumptions are made concerning the distribution of strain and stress throughout the body of the specimen at instants of maximum strain of the cycle:—The distribution of strain from axis to skin is linear; the distribution of stress conforms to Hooke's law from the axis for a portion of the radius, and for the remainder of the radius to a relation between stress and strain similar to the linear relation found experimentally between the ranges of strain and stress in thin-walled tubular specimens in alternating torsion.

Applying these assumptions, it is found that the results of certain alternating tests of solid specimens in torsion, become practically identical with those of hollow specimens, and that the author's alternating tests of hollow and solid specimens in bending are in fair agreement. The author concludes that the difference between fatigue stresses calculated from the range of torque or bending moment on the usual assumption of linearity of stress and the actual fatigue stresses, must be greater than is commonly supposed for solid specimens, and also for hollow specimens, in alternating bending.

The three other papers included in the report were "The Graphical Determination of Stress from Photo-Elastic Observations," by Professor L. N. G. Filon, which we shall reprint in a later issue; "The Thermodynamic Theory of Mechanical Fatigue and Hysteresis in Metals," by Professor B. P. Haigh; and "The Repeated Bending of Steel Wire," by Dr. W. A. Scoble; but these were not referred to at the meeting.

The reading of the three papers previously mentioned was followed by a general discussion which had to be greatly curtailed owing to lack of time. Professor F. C. Lea, the first speaker, referred to Professor Mason's paper, mentioning that Bairstow's experiments on fatigue showed that the hysteresis loops tended to diminish in area as time went on. The speaker found, however, that this was not always the case. He thought there was something to be said for the theory suggested by the author, but was not sure whether the material used in the tests had got into the cyclic condition. He queried a statement in Messrs. Wilson and Haigh's paper to the effect that the resistance of steel and iron to fatigue by simple tensile and compressive stresses is dependent on the ratio of its yield strength to its ultimate strength, and asked on what basis such a generalisation had been made. He also asked Mr. Wilson whether the fact that the maximum repeated stresses occurred only comparatively infrequently in the case of a bridge made any difference in comparison with the results obtained in a fatigue testing machine in which the stresses were repeated, say, 2,000 times per minute. There was, he said, a tendency for confusion to arise in connection with the stresses on bridges, and he thought attention should be confined to the determination of the stresses actually existing in a structure loaded in a particular manner. The assumption usually made was that the structures were statically determinate, whereas actually they were statically indeterminate.

Mr. R. L. Sackett referred to a plate-girder railway bridge constructed by British engineers at Detroit, Michigan, in 1860, which, he said, had remained in service for over fifty years, during which time both static and impact loads must have been doubled. He also referred to experiments carried out in America to determine the effect of the speed of trains on the strength of railway bridges. Professor Sir J. B. Henderson expressed appreciation of the papers forming the report, and remarked that the science of fatigue was in what the late Lord Kelvin called the "natural history" stage, during which experimental data were collected for the formation of a theory at a later stage. The only other speaker, Professor Mason, stated that he thought the impact factor was dependent upon the period of vibration of the structure.

The chairman then stated, in reference to Mr. Sackett's remarks, that he had been pleased to hear a reference made to the effect of speed on railway bridges; a matter which, he said, appeared to have been lost sight of in this country, though it had been investigated in the United States. There were good opportunities here for carrying out experiments on the subject, since there were many different portions of railway systems devoted to fast and slow traffic, respectively. He then called upon the authors of the paper to reply briefly to the points raised in the discussion.

Mr. Wilson, who spoke first, said in answer to Professor Lea, that he had not considered other metals than mild steel, the problem in regard to which was sufficiently difficult in itself. He thought, as far as anything could be tentatively suggested as an indication of fatigue, what was given in the paper was not far from the truth. With regard to the frequency of stress repetitions, he mentioned that, in Fairbairn's tests, an excessive load had been accidentally applied some 150 times and a permanent set had been produced, but this appeared to have had but little effect. He thought this had a direct bearing on the point raised by Professor Lea. Professor Cook had no observations to make and Professor Mason said, in reference to Professor Lea's question as to whether the material used had reached the cyclic state, that he thought he had used a greater number of stress repetitions than had been employed in Bairstow's experiments.

This concluded the business for the morning, and the meeting then adjourned. As previously mentioned, the members visited the Gladstone Docks of the Mersey Docks and Harbour Board in the afternoon.

Wave Shape and Earth Currents of Alternators.

The heavy programme arranged for the final meeting of the section, held on Wednesday, the 19th inst., was opened by the reading of two papers

by Professor E. W. Marchant. The first of these, of which Mr. T. H. Turney was a joint author, described a method of improving the voltage wave of alternators, especially of three-phase machines, by means of an arrangement of shunts. We shall reprint the paper in a later issue, but we may now explain that the device employs shunts adjusted to have zero reactance for the ripples it is desired to eliminate, in conjunction with a current-limiting inductance arranged in the neutral of the three-phase supply through which the shunt current produced by the ripple flows. The shunt circuit consists of an air-core inductance and condensers connected in series, while the limiting inductance is of the iron-cored type. Curves given in the paper show the effect of the device in improving the bad wave shapes of four different machines.

Professor Marchant's second paper, which we shall also reproduce later, referred to the fact that, in some modern power stations, there is a considerable current flowing through the earth lead from the neutral point of the alternator, even when only one machine is earthed. It has been found that this current is three times (or a multiple of three times) the fundamental frequency, and that it is due to a ripple on the pressure curve of the alternator between each phase and the neutral point. If such a ripple exists, a current corresponding to it will flow from each core of the three-phase cable network to the sheath, and the currents so flowing, add up, and do not cancel each other as do the three-phase capacity currents of fundamental frequency.

After the two papers had been read, the chairman, Sir Henry Fowler, invited discussion. This was opened by Mr. W. M. Mordey, who said he thought Professor Marchant rather underestimated the value of the suggestion made in his first paper. The speaker thought the arrangement would simplify the question of design, since less attention need be paid to departures from the sine form of the wave. It might also reduce the cost of construction since defects in design could be remedied after completion. He had no doubt that, in connection with existing machines, the arrangement would be useful in getting rid of troubles which might otherwise necessitate the replacement of the plant. Professor F. G. Baily agreed with Mr. Mordey that the value of the device had been rather under-estimated by the author, remarking that it would be useful in minimising troubles due to harmonics. An over-run induction motor, he added, produced harmonics which rendered the wave form practically unrecognisable as a sine wave, and he thought it would be useful to fit Professor Marchant's device close to such a machine; it would also be extremely useful for laboratory experiments, requiring the use of a sine wave. Professor G. W. O. Howe said he wished to associate himself with the previous speakers as to the utility of the device, which, he considered, would be of special importance in connection with the electrification of railways on account of the interference produced in telephone lines by harmonics. He mentioned, however, that tuned circuits had already been used on the Continent in connection with electric generators for short-circuiting harmonics, but stated that the inductance in the return lead, which acted as a choke to the harmonics only, was a novelty.

Dr. T. F. Wall inquired if it would be necessary to use a separate tuned circuit for each harmonic, and asked for information as to the cost. He agreed that the heating effects due to the device would be small, but doubted whether the iron losses would be negligible. Professor F. C. Lea said he was interested in the device and proposed to try it in connection with an electromagnetic alternating-stress testing machine for the purpose of obtaining a pure sine-wave loading in the specimen. The last speaker, Mr. H. Jack, said he could confirm Professor Howe's statement as to the previous use of similar apparatus, and mentioned that the British Thomson-Houston Company had also employed means for improving the wave shape of alternators by the elimination of harmonics. He pointed out, however, that it was now much easier than formerly to design a generator to give a pure sine wave by using a fractional number of slots per pole per phase instead of a whole number.

In his reply, the author said he had not got out an estimate of the cost of the apparatus, but thought it would not be very serious. He was not aware that resonant circuits had been used in power supply systems for eliminating harmonics, and added that a well-known firm of Swiss engineers, who had encountered difficulties of the kind, had adopted the method he had suggested. He thought that resonant circuits had been used on telephone lines, but not on the machines themselves. (Professor Howe here confirmed his previous statement and promised to supply references.) To Dr. Wall's query as to iron losses, the speaker replied that these might be slightly increased, but he had no definite information; the efficiency was certainly not much affected.

Electric Propulsion of Ships.

The next item on the programme was a paper by Mr. F. H. Clough dealing with the advantages of the electric system of ship propulsion. In the unavoidable absence of the author, this paper, which we shall publish at an early date, was read by Mr. H. Jack, who afterwards exhibited a kinematograph film illustrating the action of a synchronous motor and also showing the manufacture and installation of the electrical propelling machinery of the ss. San Benito.

The first speaker in the discussion on this paper was Mr. A. T. Wall, who said that the author had dealt with the subject from the engineer's point of view, but added that electric propulsion had many advantages from the shipbuilders' standpoint, particularly in the case of a vessel, such as the San Benito, which was insulated throughout for the carriage of fruit. The great point in a ship of that kind was to carry as much fruit as possible, and by placing the generator in the engine-room and the motor at the after end of the ship, the shafting was dispensed with and increased space rendered available for cargo. He thought turbine engineers would dispute the figures given in the paper for the losses in gearing, viz., 10 per cent. for double-reduction and 8 per cent. for single-reduction, but added that the system to be employed was not decided by a matter of 1 per cent. or 2 per cent. either way. The speaker pointed out, however, that although the author had been able to show that electric propulsion was advantageous in the case of a fruit boat, the same advantages did not occur in all vessels. He also called attention to a statement in the paper to the effect that the area of the propeller was proportional to the area of the mid-ship section, pointing out that this was a general statement which would need qualifying for the speed and type of ship.

Professor Marchant, the next speaker, said he had seen a Swedish ship fitted with Ljungström turbo-generators and an electric motor, and had been greatly impressed by the saving of space between the motor and the turbines. He asked, however, if Mr. Jack could give further information as to the overall efficiency of electric propelling machinery, remarking that the figure of over 90 per cent. given in the paper seemed to be very high; he wished to know how the figure had been arrived at. Professor F. G. Baily, who continued the discussion, said electric propulsion, although directly advantageous in many applications, might be entirely ruled out in the case of warships. In high-speed vessels it would not do to put the motor too far aft, as the propelling machinery must be situated near the centre of the ship. He also pointed out that, with warships steaming in a squadron, extremely close speed regulation was essential. There were, however, many applications in which these objections would not apply. Mr. C. Rettie, who followed, spoke of the slow rate of progress in the development of electric ship propulsion. He wished to see purely British firms take up the matter, but called attention to the necessity for installing only well-tried apparatus. He also referred to the electrical propelling installation of the ss. Wulsty Castle, on which Ljungström turbines running at 3,000 r.p.m., were employed to drive motors connected to the propeller shaft by gearing; the latter, he said, might have been eliminated if slower-running turbines had been employed. Professor W. H. Watkinson spoke on the subject of Diesel engines, remarking that the direct connection of these engines to the propeller shaft had many advantages over any form of gearing unless the engines ran at very much higher speeds than were used at present. Mr. R. L. Sackett said he had examined a single-reduction geared-turbine installation which had run 160,000 miles, and had been unable to detect any signs of wear. He had also spent some time in the engine-room of a vessel with double-reduction gearing and had been struck with the compactness of the machinery.

The time available for the discussion of the paper having elapsed, the chairman called upon Mr. Jack to reply for the author. Mr. Jack first explained that the figures given in comparing efficiencies had been taken from a paper by Mr. W. J. Belsey, read before the Institution of Engineers and Shipbuilders in Scotland, and gave further particulars of these in reply to Mr. Wall and Professor Marchant. To Professor Baily the speaker pointed out that the early applications of electric propulsion were to the warships of the United States Navy, and it was its success in this application which led to the use of the system on commercial ships. It was not necessary for the motor to be placed aft; it could be installed in the engine-room if necessary and occupied only the same space as reduction gearing. With regard to speed regulation, the speaker pointed out that, in the San Benito, the speed could be adjusted by varying the speed of the turbine in exactly the same way as could be done in a turbine-driven ship. He thought it undesirable to employ gearing on electrically-driven ships, as had been done in the case of the Wulsty Castle, and in connection with Professor Watkinson's remarks as to the advantages of a direct drive with Diesel engines, pointed out that the latter were limited as to the amount of power which could be developed. The speaker finally expressed his appreciation of the manner in which Mr. Clough's paper had been received.

Mercury-Arc Rectifiers.

A paper by Mr. R. L. Morrison dealing with the conversion of alternating current to direct-current by means of the mercury-arc rectifier was then taken. In this paper, which we shall reproduce in a future number, the author first calls attention to the need for a simple stationary converter comparable with the static transformer. After explaining the valve action of the mercury arc and the fundamental considerations underlying it, he points out that the high efficiency of this form of converter when supplying direct-current at high pressures, renders it particularly suitable for use in connection with railway electrification work. The paper illustrates and describes single-phase and polyphase rectifiers, showing the wave form produced in each case, and also deals with the special transformers used to enable both halves of the alternating-current wave to be utilised. The construction of large rectifiers is described, and the means of sealing them to prevent the ingress of air are explained. The effect of the nature of the anode material on the continuous operation of the plant is discussed and the main auxiliaries (vacuum pump, ignition converter, &c.), are described. Particulars are given of the sizes now manufactured, and their operation in conjunction with other types of converters is discussed. The use of the rectifiers for supplying high-tension direct current is dealt with, and details are given of those at work on the Midi Railway system of France. Overloading and automatic operation are also referred to.

Professor E. W. Marchant, the first speaker in the discussion on this paper, said he could confirm all the author had said as to the advantages of the mercury-vapour rectifier. With regard to fluctuations in the direct-current voltage, he did not think it necessary to employ a 12-phase system, as perfectly steady currents could be obtained with six phases, or even with three. The great advantage of the mercury-vapour converter over the rotary converter was that the former had no rotating parts and was also extremely simple. The only serious difficulty experienced in a plant at Garston was due to the effects of sudden short circuits which sometimes put the rectifier out of action, but he thought this difficulty had been overcome in plants of more recent design. He finally remarked that the fact that the efficiency of the mercury-vapour converter increased with the load rendered it particularly suitable for traction work. Professor F. C. Lea asked for particulars as to the relative cost of

different methods of converting alternating current to direct current, and also inquired if any trouble had been experienced in the maintenance of the vacuum in mercury-vapour converters.

The next speaker, Mr. E. M. Hollingsworth, asked for information as to the efficiency of mercury-vapour rectifiers in comparison with rotary converters, stating that it was generally understood that the latter were better for direct-current voltages below 1,500. Rotary converters, he added, were as reliable as it was possible for electrical machinery to be. The speaker also referred to the auxiliary plant required in connection with mercury-vapour rectifiers and inquired as to the risk of breakdown in this. He did not agree with the author that the bulk of the electrical energy distributed was in the form of direct current, stating that it was now distributed, as far as possible, by alternating current. The speaker concluded by expressing the opinion that the mercury-vapour rectifier had a big field of utility in the form of small units for battery charging, but that it would not make very rapid strides for lighting or traction at voltages below 1,500.

Another speaker, whose name was not announced, inquired how the increased size of the transformers used affected the cost of the installation, and Professor G. W. O. Howe, after expressing admiration for the manner in which the mercury-vapour rectifier had been developed by Messrs. Brown, Boveri and Co., pointed out that all the difficulties had not yet been overcome. Some troubles, he said, had been experienced with an installation at Glasgow. In connection with the application of the mercury-vapour rectifier to traction work, the speaker pointed out that while it was possible to avoid the use of rotary machinery in sub-stations, this could not be done on the trains. If high voltages could be handled in the motors on a train, he added, it ought to be a simple problem to deal with them in a sub-station.

No other member wishing to speak on the paper, the chairman then invited the author to reply to the points raised in the discussion, remarking, in doing so, that he had seen the plant at Battersea which had been referred to in the paper. Some little trouble had been experienced with this, but there had been no interruption in the supply. Mr. Morrison, in replying, admitted that trouble had occurred with the rectifier installation at Glasgow which, he stated, was the first of that particular size to be put into operation. Intense back-firing had occurred, but the rectifiers had been replaced and the new ones had now been running for some weeks without any trouble. At Garston, he added, the anodes had been changed, the new ones being of a different material, and this alteration had proved quite effective. He had intentionally avoided referring to the matter of cost, but as particulars had been asked for, he stated that the cost might be a little greater than that of rotary converters in some cases and about the same in others, the actual cost of any particular installation being dependent upon the conditions to be complied with; for high voltages, he added, the cost of mercury-vapour rectifiers was generally lower than that of rotary converters. With regard to the efficiency of mercury-vapour rectifiers in comparison with rotary converters, he said, the figures given in his paper, in its complete form, would show that the former was better in practically every case for direct-current voltages exceeding 400, unless induction regulators were necessary. Breakdowns of auxiliary plant, he said, were extremely rare as the plant was particularly well constructed. The transformers required with mercury-vapour rectifiers were certainly larger than those for rotary converters, the difference amounting to about 50 per cent. in a six-phase installation. With reference to Professor Howe's remarks as to the use of rotary machinery on trains, the speaker stated that there was now no difficulty in designing direct-current motors to work at terminal pressures of 2,000 volts, while, with a three-wire system, pressures of 4,000 volts could be employed.

An Improved Form of Squirrel-Cage Induction Motor.

Dr. T. F. Wall was then called upon to read his paper on a "Squirrel-Cage Induction Motor with High Starting Torque and Low Starting Current in the Line." This paper describes a motor of the squirrel-cage type in which the rotor conductors are built up as composite bars, each bar being formed of a central copper rod surrounded by a steel sheath, the outside of which is coated with copper, to a suitable thickness, by electro-deposition. Each rotor conductor is thus, in effect, a simple form of transformer in which the central copper rod is the primary winding, the steel sheath the magnetic core, and the copper plating the secondary winding. The effect of the arrangement is such that, at starting, when the currents in the rotor bars are at line frequency, the bars offer a relatively high resistance to the passage of the current, but when the motor is running and the frequency of the currents corresponds to the slip, the resistance of the rotor bars is practically the same as it would be to a direct current; in other words, the inherent resistance of the rotor conductors is proportional to the frequency of the alternating current which flows in them. From this it follows that the motor has starting characteristics similar to those of a machine with a wound rotor and starting resistance, in conjunction with the simplicity, strength and reliability of a motor of the squirrel-cage type.

The discussion that followed the reading of the paper was opened by Professor F. G. Baily, who expressed his appreciation of the author's ingenuity in tackling the problem of the squirrel-cage motor. This machine, he said, was practically perfect, except for its starting qualities, and he regarded the improvement described in the paper as one of the most important. Mr. H. Jack, the next speaker, also congratulated the author, but stated that something similar had been produced in America in connection with synchronous motors; he did not think, however, that the device referred to had been tried in this country. There was a wide field for the use of squirrel-cage motors which were most reliable machines, and any improvement which would increase the number of possible applications was useful. Professor Sir J. B. Henderson and Professor E. W. Marchant both congratulated the author, and Mr. C. Rettie, the next speaker, referred to the importance of the regulation of induction motors in connection with ship propulsion. The author, he said, had referred to fixed voltages, but the difference between ship work and land work was that in the former the voltage was not fixed. The motor could thus be easily run up by increasing the applied voltage. Professor G. W. O. Howe pointed out that the idea of utilising skin effect was old, but the problem had been how to do so in the most effective manner. The author's solution, he thought, was an admirable one and test results would be awaited with interest. One defect of the induction motor, he remarked in conclusion, was its low power factor. High power factors were now required, but he was afraid they would not be obtainable if a three-phase supply were used to produce the flux as well as the torque.

Dr. Wall then replied to the discussion, first expressing thanks for the manner in which his paper had been received. With regard to Mr. Jack's remarks to the effect that a similar solution had been obtained in America, the speaker said a number of proposals had been made, but he had thoroughly searched the records and had found none corresponding to his own. Some American engineers who had seen his work had referred to a method in which a central core was employed with a copper tube instead of a steel tube. He supposed this had some effect, but could not understand its action. With regard to the question of power factor, he stated that the squirrel-cage type was superior to the slip-ring type, and he thought it would be found, when the test results were available, that the power factor of the machine he had described was higher than that of a slip-ring machine, but slightly lower than that of an ordinary machine of the squirrel-cage type.

The Mechanism of Gas Ignition and the Lighting of Coal Mines.

Two communications, both by Professor W. M. Thornton, dealing, respectively, with the mechanism of gas ignition and with a safe method of lighting coal mines formed the next items on the programme, and as these were of a complementary character they were dealt with by the author in succession. In the first communication, the author explained that the two methods of spark ignition used in engineering work were the disruptive discharge at high voltages and the arc formed at the point where a circuit was broken. The former, he said, was a case of ionisation by collision, but he pointed out that ignition did not depend entirely upon the sparking voltage. For each inflammable mixture there was a certain intensity of spark necessary for ignition, and below that intensity it was possible to pass sparks indefinitely without producing an explosion. It was necessary for the production of ions to take place at a certain rate which bore little or no relationship to the total energy dissipated in the spark. Ignition, he said, occurred when a critical rate of electrical activation of the combining gases was reached.

Ignition by means of a momentary arc was mainly ionic and not thermal, but recent observations on the ignition of hydrogen-air mixtures, the author said, had given more direct evidence of its character. Experiments with alternating currents at 85 volts and 250 cycles had shown that, after breaking a 10-ampere circuit at iron poles 50 times in air alone, ignition of a 35 per cent. mixture of hydrogen in air occurred with a circuit current of 0·4 ampere, while, after sparking freshly cleaned poles the same number of times in pure hydrogen, ignition of the same mixture could not be obtained with a circuit current less than 6 amperes. It was thus clear that this form of ignition did not depend upon the energy of the arc. The author's conclusion was that ignition did not depend upon the heat energy of the arc or upon the total electron discharge, but upon the emission of that which was suppressed by the hydrogen, viz., oxygen absorbed by the poles in contact with air and activated by the combined effect of the thermionic discharge and the strong electric field at break.

Professor Thornton's second communication dealt with some extremely interesting observations as to the effect of frequency upon the ignition of methane. These observations show that by the use of frequencies much higher than now employed for power purposes, greater safety can be obtained in the use of electricity in mines. It appears that ignition of the most explosive mixture of methane (fire-damp) in air, *i.e.*, a mixture containing 9·5 per cent. of methane, takes place on the breaking of a 200-volt direct-current circuit carrying 0·5 ampere. With a 50-cycle circuit, on the other hand, the least current which will produce ignition when broken is 6·5 amperes, while at 160 cycles, the corresponding current is 23 amperes. At a voltage of 20 and a frequency of 160 cycles, it is impossible to ignite the mixture with a clean break of less than 150 amperes.

Professor Thornton then referred to a system of mine lighting, now being tested, in which 160-cycle current at 15 volts is supplied to a number of circuits, each including about 20 portable lamps. The lamps each have two filaments of different sizes, the smaller being connected to a battery in the lamp body and giving 2 candle-power, which is sufficient for the miner to travel by. Current at 15 volts is supplied to the larger filament when the lamp is connected to a plug, and, by this means, the light available at the working face can be increased to 15 candle-power or more. The small filament is cut out when the larger one is in use, but, in the event of a failure of the 15-volt current, work can be continued by the aid of the small filament supplied from the battery. Each plug has a special interlocking contact, which prevents the circuit from being broken until the lamp is switched over on to the battery, so that there is no risk of open sparking. The high-frequency circuit also includes a choking coil which limits the current in the event of a short circuit to a value less than that required to effect ignition of a 9·5 per cent. mixture if broken in the open. The system is thus protected by all the usual devices against excess current, but its chief safety lies in the use of the high-frequency currents.

The discussion on these communications took the form of a series of questions by various speakers, each question being answered immediately by Professor Thornton, but as most of the points raised

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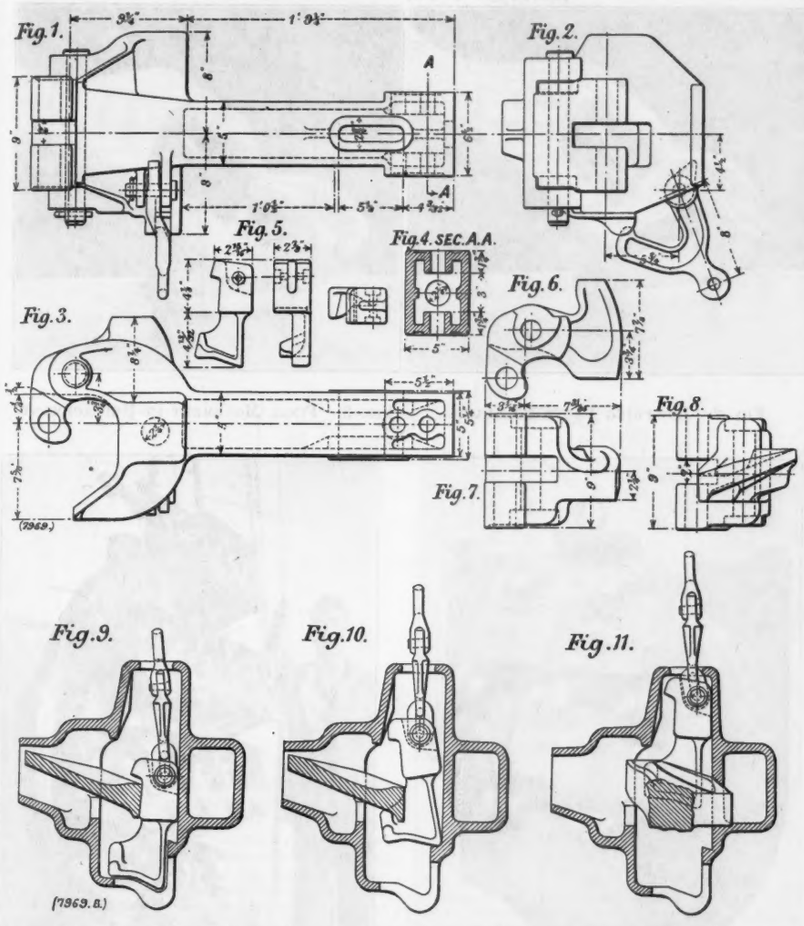


are covered in the abstracts given above we may pass on to the next and final paper.

DEVELOPMENTS IN WIRELESS RECEPTION.

This bore the title given above and was read by Mr. J. Scott-Taggart. It was divided into two parts, the first of which described a method invented by the author for reducing the effects of interference and atmospherics by frequency multiplication. The invention involves the increasing, at the receiving station, of the frequency difference between the desired and undesired signals, so that they can be more easily separated out by the heterodyne method of reception using selective high-frequency receiving circuits. The paper was intended to give only an outline of the system, further technical details of which will be made public at a later date. The second part of the paper described a number of reflex, or dual amplification, circuits designed for the reception of broadcast telephony with the minimum number of valves.

But little time was available for discussing the paper, and Professor G. W. O. Howe, the first speaker, merely expressed appreciation of the author's work. Professor E. W. Marchant inquired whether there was any limit to the number of aerials which might be used for the reception of broadcast telephony, and whether there was much absorption of energy in the frequency multiplier mentioned by the author. Mr. Scott-Taggart, in replying, said there appeared to be no limit to the number of aerials employed, and also stated that there was a loss of energy in the frequency multiplier, but this could be compensated for by high-frequency amplification. The system, he added, was only intended for long-distance working, for which application the separation of interfering signals and the reduction of atmospheric disturbances was of greater importance than the use of a few additional valves.

The chairman then said that the business of the section had been completed for the year and also remarked that it was a matter for congratulation that the audience at the last session was greater than that at the first. After a vote of thanks to the chairman, proposed by Professor F. C. Lea, and seconded by Professor G. W. O. Howe, had been carried with acclamation and the chairman had briefly responded, the meeting terminated.

(To be continued.)

THE MAJEX CENTRAL BUFFER COUPLER.

WHILE we, in this country, continue to use the simple three-link or screw-link coupling, with side buffers, on our railway rolling stock, and the central buffer coupling makes little headway, except in a very limited way for certain classes of passenger stock, the position is very different in other parts of the world, and even of the Empire. The improvement of methods of coupling railway vehicles is a very favourite subject among inventors, but it is quite probable that if the transition period could be satisfactorily surmounted, existing types of central couplers would be found to serve, and the multiplication of types would be superfluous.

The central buffer coupling has, of course, been in use for many years on the metre-gauge lines in India and on many other systems, as for instance South Africa, but its development has been most marked in America. We do not propose to enter into the early history of the coupler in that country, but it is interesting to note that prior to the war the universal adoption of the M.C.B. standard coupler had led the manufacturers of that country to produce a large number of different types, all of which conformed to M.C.B. standards as regards profile, tests, &c., but which differed so in details that replacements became a very troublesome matter. About 1910 the increasing size of freight stock and of trains began to show up the weak points of the then standard, and in anticipation of further developments steps were taken to review the whole question. The ultimate, though not immediate, result was that a new standard was adopted, now known as the type "D" coupler, and was started on its career with the orders for standard vehicles placed during the period of Government control.

The type D coupler is much heavier and stronger than its predecessors. The coupler proper weighs about 400 lb., while previous standard patterns weighed about 300 lb. The new knuckle weighs 100 lb. against 60 lb. to 70 lb. in the earlier M.C.B. forms. At the present time the largest American stock weighs, loaded, about 160 U.S. tons, and trains up to 16,000 tons in weight have been handled as we have recorded in our pages. These loads are far ahead of developments in other countries, and it is scarcely necessary to consider the adoption elsewhere of anything quite so robust as the type D coupler at present. Those countries therefore which are turning their minds to the central buffer are usually to be found investigating the possibility of the older M.C.B. form, or developments therefrom.

To show the extent of the movement, not always realised in this country, outside North America the M.C.B. type of coupler is used largely in Brazil and on the narrow gauge lines of the Argentine. It has been adopted in South Africa for passenger stock and is being considered for freight stock also. On the Rhodesian Railways, and the Katanga Railway in the Belgian Congo, it is used for both classes. It has been adopted universally in China. Last year the Japanese Government placed orders for 66,000 with the object of converting their stock to it. In Australia it is being considered and experimentally tried in New South Wales and Victoria. The South Australian Government are considering its adoption in a pending order for wagon stock, while in India the subject is also under consideration, trials having been already made in some cases, while a report has just been published going very fully into the whole subject so far as it concerns the broad gauge (5 ft. 6 in.) lines of the Indian State Railways. This report is drawn up by Mr. H. G. Norman White, deputy locomotive superintendent. It discusses the types of coupler available, the possibility of manufacture in quantity, the cost and method of conversion and so on. On many points Mr. White gives no definite recommendations, arranging facts merely for the use of any body which may be appointed, should the matter be proceeded with so far as to necessitate a committee or other body for the purpose of drawing up a policy and programme of conversion. Mr. White visited this country and America and Belgium. He investigated the possibilities of certain new designs, but came to the conclusion that the adoption of the type so well known in America would be preferable to that of any untried device.

Mr. White's conclusion with regard to the type D coupler is that nothing so heavy will be required for many years, and he points out that if any of the lighter patterns of M.C.B. coupler be adopted they will all couple with the type D if and when it ultimately has to be adopted.

As we have pointed out the original M.C.B. coupler developed weaknesses in heavy service, but the coupler would probably be amply strong enough for Indian service. However, there are now available improved patterns of the coupler, practically the same weight (300 lb.) as the old M.C.B. design, but much stronger, the metal having been better disposed, and the parts stiffened up where previous failure showed this to be desirable. One of these improved patterns is that known as the Majex coupler, illustrated in Figs. 1 to 11 annexed. This coupler is designed to the new contour, known as the No. 10. In this contour the hook of the knuckle is made a little more pronounced and the knuckle is thickened up considerably, so that there is more metal at the pivot.

The Majex coupler is manufactured by the Buckeye Steel Castings Company, of Columbus, Ohio, whose, general foreign agents are Messrs. Davis and Lloyd, of 26, Victoria-street, London, S.W. 1. This coupler is unique in several ways. The coupler proper has only four parts, the coupler head, the knuckle and pin and the lock block. The knuckle is arranged with a curved inclined tail, and it is thrown by raising the lock block. The knuckle is illustrated in Figs. 6 to 8 and the lock in Fig. 5. The diagrams, Figs. 9 to 11, will assist in making the action clear. When the lock is raised right up, the bottom lip on the lock comes in contact with the tail of the knuckle and on account of the slant of the latter, further lifting of the block throws the knuckle open (Fig. 11). When the strain is removed from the lifting chain and the knuckle is closed by another buffer coming into contact with it, the lock falls to the bottom of its recess (Fig. 9) when the upper part of the block fouls the front of the knuckle tail, thus preventing

ISMAILIA VALVES FOR PUMPS AND MAINS.

FIG. 1. REPLACING VALVE, FIRST OPERATION.

FIG. 2. LOWERING VALVE TO SEAT.

FIG. 3. FINAL MOVEMENT IN REPLACEMENT.

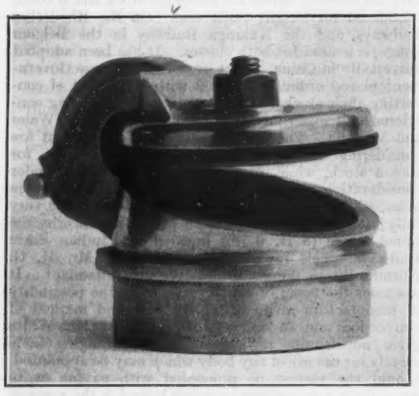


FIG. 4. ISMAILIA VALVE WITH FACING.

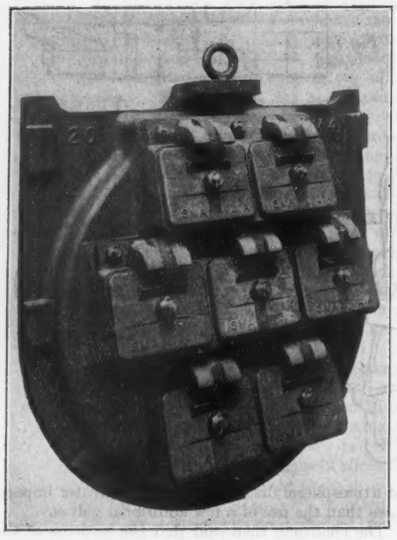


FIG. 5. 20-IN. REFLUX VALVE.

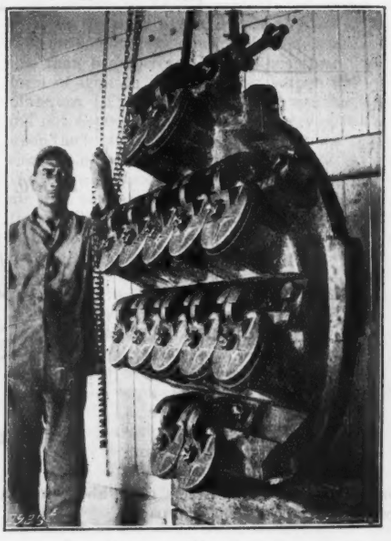


FIG. 6. VALVE PLATE FOR 200-H.P. PUMP.

this part from swinging to the open position. If the knuckle is closed and it is desired to set the coupler to open on drawing vehicles apart subsequently, the lock is lifted and becomes canted on to a ledge (Fig. 10) in which position the block no longer fouls the tail, which is then free to swing open. The lock block is either operated from the top or bottom according to the type of stock, or preference of the railway. Figs. 1 to 4 show the under-lift type, while the sections, Figs. 9 to 11 show the top-lift type. The same casting is used for both, but when used for the top-lift, a 2¼ in. hole, as dotted in in Fig. 3, is drilled in the head. The hole below for the under-lift lever is cored in the casting.

The design of the lock block eliminates special parts for throwing the knuckle, and the block is entirely contained within the coupler head. The knuckle is provided with lugs at the pivot extending into recesses in the coupler head, taking practically all direct pulling and buffing stresses off the pivot pin. The buffing forces are taken by large shoulders at the back of the pin hole. The interlocking of the knuckle lugs and tail with the head and lock make it possible to remove the pin without opening the knuckle.

To meet the requirements as regards transition in the case of various types of American coupler it is proposed to slot the knuckle horizontally and provide a cored hole for a coupling pin. This system has been previously adopted for coupling up with link-fitted stock. As regards Indian standard stock the change-over would require modification of the side buffing spring given in stages. This appears to be quite feasible with the particular type of side buffer used.

ISMAILIA VALVES FOR PUMPS AND MAINS.

PUMPS must frequently be installed to deal with liquids which contain solids in suspension and other foreign matter. In such cases there is an ever-present tendency to valve troubles. These are due to the deposit of some of the substances on the valve seats which prevents the complete closing of the valves and eventually puts them out of action. In addition to these effects, there is also a clogging action, due to the same cause, at the pin joints, in those cases where the hinged type of valve is in use. The shutting down of the plant for overhaul is necessary whenever the results of these accumulations are shown. The reduction of the time required for this imperative operation is a matter of very great importance. In overcoming the tendency to these actions the replacement of a single heavy valve by a number of small ones gives a certain advantage. Small valves are to be preferred because of their easy accommodation to the seat and also for the reason that their wear is small. In consequence, they can be kept in efficient working condition for comparatively long periods. From the standpoint of the time taken in overhauling, the use of small valves of the hinged type cannot, however, be regarded as free from objection, unless the system of construction is such that easy and quick removal of the pins of the hinges is possible or the system of construction does not necessitate their use.

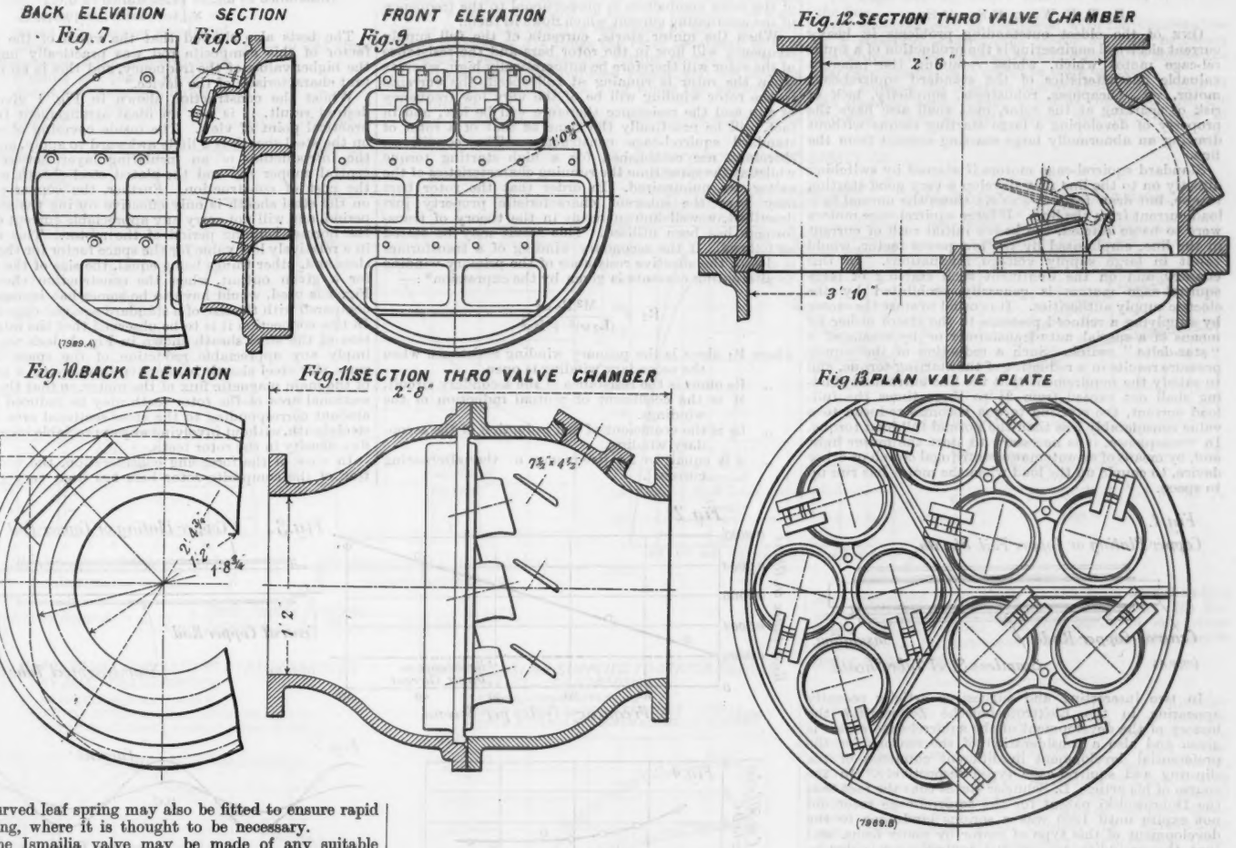
A valve in which the ordinary hinge arrangement has been eliminated from the design, was introduced for use at the Ismailia Pumping Station, at Cairo, by Mr. E. C. Bowden-Smith, M.I.Mech.E., of 17, Victoria-street, London, and its application is now being extended to the general field of service where the liquids contain sand, grit, refuse and other solid matter. This valve, named Ismailia, after the place at which the difficult pumping conditions provided the necessity for its invention, is illustrated on this page and on page 393.

The conditions which the designer set himself in the production of this valve were the provision of the clear opening of the flap valve, with the free seating property of the central spindle disc type and the additional, and by far the greatest, advantage for its particular field of service, the characteristic of being quickly removable and replacable by hand without the use of tools.

In construction the Ismailia valve is exceedingly simple. It is of the flat type, with an extension in the form of a curved arm, with a projection on its underside and shaped at its end to provide a pin at each side. To one side of the valve seat are two extensions of elbow shape. In use, the arm of the valve comes between these erections and the pins are situated under the bend at the elbow.

Figs. 1, 2 and 3 show how the valve is put in place on its seat. When it is lifted so that the pins or lugs at the end of its curved arm are on the top surfaces of the projections at the back of the seat (see Fig. 1) a sliding motion is all that is necessary to carry the pins beyond the elbow and, while the valve is held to the seat, by a forward movement they can be brought under the edges just as is shown in operation in Fig. 3. The valve cannot be put back in any but its correct position, neither can the action of the liquid impart the necessary consecutive motions to release it from its proper working position. For removal the operations are reversed, but it is necessary to note that the front of the valve must be kept depressed if the pins are to be got free from the underside of the projections. These valves may be erected in either a vertical or horizontal position. In cases where clear water and fluids free from foreign matter are dealt with, it is common to use the metal to metal arrangement shown in the first illustrations, but facings of leather or other material (Fig. 4) may be fitted if the properties of the fluid necessitate their use. A simple circular plate with a bolt and nut is then used to hold the facing in place.

ISMAILIA VALVES FOR PUMPS AND MAINS.



A curved leaf spring may also be fitted to ensure rapid closing, where it is thought to be necessary.

The Ismailia valve may be made of any suitable metal, of any desired shape or dimension, but the most appropriate size is that which facilitates the easy handling which is an essential requirement for removal and replacement. The valve plate shown in Fig. 5 is fitted with seven rectangular valves, the arrangements of which are similar to those in Figs. 7 to 11, but the equipment is of larger size. Both are examples of reflux valves used on pumping mains. The diaphragm on which the seats are cast is effectively stiffened with ribs. The great advantage of the use of small easily-handled valves is apparent from Fig. 11, where the small hand-hole shown is all that is necessary for the inspection and withdrawal of the valves in place of a massive cover.

In Fig. 6, the valve plate for a 200-h.p. pump is shown. In this case the circular valves are set out in four horizontal rows. Another layout for the circular type of valve, and one which has a great advantage in giving a large proportion of the total area for opening is shown in Figs. 12 and 13. The plate in this case is provided with effective rib stiffeners. Simple hand-holes again serve for the inspection and removal of the valves. As a number of small valves work much more easily and rapidly than a single large one, advantage may sometimes be taken of this in increasing the speed of working. In cases of drainage or sewage pumps, this may prove of value in giving freedom to deal with variations in volume on occasion, without the necessity for starting up another pumping unit.

While the greatest advantage of the use of the Ismailia valve is to be obtained with multiple valves in large installations, there are other cases, such as in bilge pumping, in mining operations, in the oil fields and in general contractors' work, where the advantages possessed by this easily removable valve are obvious.

TECHNICAL CLASSES FOR THE UNEMPLOYED.—The Stalybridge Higher Education Committee has decided, if the consent of the County Council can be obtained, to organise technical classes for the unemployed, providing that a sufficient number express themselves willing to take the opportunity. Classes for both males and females, to be held in the day time, would be arranged. The committee has also decided that students in technological subjects attending the evening classes may, if they are out of work, continue their studies at the school in the day time. This is an excellent arrangement.

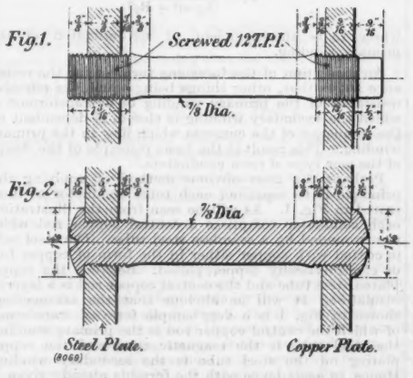
LOCOMOTIVE COPPER STAYS.

TO THE EDITOR OF ENGINEERING.

SIR,—The form of copper stay suggested by your correspondent, Messrs. Alfred Herbert, Limited, in your issue of September 7, is not likely to prove satisfactory, for the following reasons:—

1. The plug does not extend through the stay for the full thickness of the plates, and would therefore only tighten the outer threads.

2. The stay is weakened by the plug hole at the point where the greatest stress is located, namely, at the inside of the plate, and where in consequence practically all fractures of stays occur.



3. When the stay heads burn off, the plugs would drop out. The stay would in consequence tend to leak and become very unsafe, as it would be liable to collapse and pull through the plate.

I cannot see that the form of stay suggested meets any of the improvements enumerated in the penultimate paragraph of the letter; it would be more costly to manufacture, less efficient in working, and would require more frequent replacement.

The cost of manufacture of copper stays is a very small item compared with the cost of replacement. To remove a defective stay as large a hole as possible has to be drilled through its full length, reducing it to a mere shell, which is then removed with a chisel, a costly operation involving considerable care to ensure that the threads in the plate are not damaged. At running sheds this hole is drilled by hand with a ratchet brace, but in the large workshops pneumatic drills are generally used. It is therefore of much greater importance to increase the life of stays than to reduce the cost of manufacture.

Far more stays have to be renewed because the heads are burnt off than on account of them being broken.

It has been found that the heads of stays last longer if the threads are turned off that portion of the stay which is hammered over to form the head—the fire appears to lick into the hammered-over threads if they are not removed and burns the head off quicker. The drawing shows the form of stay which I find gives the best results.

Yours faithfully,

H. N. GRESLEY.

London and North-Eastern Railway, King's Cross Station, London, N. 1, September 19, 1923.

NORMALS OF METEOROLOGICAL ELEMENTS.—A book prepared by the Meteorological Office of the Air Ministry and recently published by H. M. Stationery Office, gives the normals of the meteorological elements for 30 selected places in the British Isles. The book comprises tables from which it is possible to see at a glance the average temperature, and the highest and lowest temperature which may be expected for each month of the year. Similar information is given with regard to rainfall, and additional tables show the average number of days on which thunder, hail, snow, frost and fog occur in each month of the year. The price of the book, which will be particularly useful to agriculturists, medical men and others requiring information as to the average weather conditions in various localities, is 3s. 6d. net.

THE CONGESTION OF CALCUTTA.—Congestion of traffic is not a problem merely of the greater cities of European or North American civilisation. Bombay and Calcutta both have troubles to face in this connection, arising largely from the fact that business blocks are supplanting dwelling houses in the central areas, and the population requires greater facilities for travelling to and from work and business. The situation as regards Calcutta has been analysed by Mr. T. A. F. Stone, A.M.I.E.(Ind.), and his arguments and conclusions formed the subject of a comprehensive paper presented by him to the Institute of Engineers (India) some while ago. In this Mr. Stone considered many of the factors affecting movement in towns on general lines and applied his conclusions to the case of Calcutta, arguing in favour of underground, overhead and circular railways, in the city, and the electrification of suburban services.

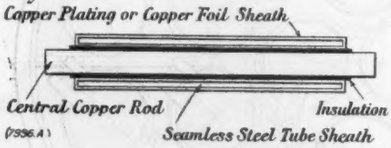
SQUIRREL-CAGE INDUCTION MOTOR WITH HIGH-STARTING TORQUE AND LOW-STARTING CURRENT IN THE LINE.*

By T. F. WALL, D.Sc., D.Eng.

ONE of the oldest outstanding problems in heavy current electrical engineering is the production of a squirrel-cage motor which, whilst retaining the inherent valuable characteristics of the standard squirrel-cage motor, viz., cheapness, robustness, simplicity, lack of risk of sparking at the rotor, etc., shall also have the property of developing a large starting torque without drawing an abnormally large starting current from the line.

Standard squirrel-cage motors if started by switching directly on to the line may develop a very good starting torque, but draw from five to six times the normal full-load current from the line. If large squirrel-cage motors were to be so started, the heavy initial rush of current in the line, emphasised by the low power-factor, would result in large supply voltage fluctuations. In this country and on the Continent such starting of large squirrel-cage motors is generally prohibited by the electric supply authorities. It is usual to start the motor by supplying a reduced pressure to the stator either by means of a special auto-transformer or by means of a "star-delta" switch. Such a reduction of the supply pressure results in a reduction of the starting torque, and to satisfy the requirement that the line current at starting shall not exceed from 2½ to three times the full-load current, the starting torque becomes reduced to a value considerably less than the normal full-load torque. In consequence, it is necessary to start the motor light and, by means of an automatic centrifugal clutch or other device, to couple up the load when the motor has run up to speed.

Fig. 1.



In two interesting and suggestive articles recently appearing in the Elektrotechnische Zeitschrift† the history of the development of the squirrel-cage motor is given and also a consideration of the reasons for the preferential development in different countries of the slip-ring and squirrel-cage types respectively. In the course of his article, L. Schueler states that the fact that the Dobrowolski patent for the squirrel-cage rotor did not expire until 1905 was a serious hindrance to the development of this type of motor by many firms, and that the prejudice against the squirrel-cage motor in Germany is largely due to the difficulties to which this patent gave rise. He further states that the European public have become accustomed to the higher cost of the slip-ring motor and the superior running characteristics of large squirrel-cage motors are not familiar to them. Moreover, the electric supply authorities have learnt to appreciate (from their point of view) the superior starting characteristics of slip-ring motors and have encouraged, if not insisted on, the installation of the slip-ring type.

Many methods have been proposed and tried with a view to enable the squirrel-cage motor to meet the competition of the slip-ring type. In particular, the double wound squirrel-cage rotor of Boucherot has had a certain limited application. In the discussion at Liverpool on the late Dr. Kapp's paper on "The Improvement of Power Factor," Mr. C. Rettie states: "The first battleship in America fitted with electric drive had squirrel-cage induction motors having two windings on the rotor with high and low resistance respectively. The efficiency was so low, however, that in the other ship fitted up by the General Electric Co. of America the system was altered, the principle being the same, but a winding on the rotor was introduced with slip-rings to raise the power-factor, the winding being cut out when the motors were up to speed."‡

A discussion of the Boucherot type of motor has been given by the present writer in a recent article§, and the disadvantages of this type as compared with the standard squirrel-cage motor have been considered with the aid of a numerical example. Another proposal was made many years ago by H. M. Hobart to utilise the well-known "skin effect" in iron conductors, but the method has not achieved the purpose intended.‖

Principle of the New Type of Squirrel-cage Motor.—The new type of squirrel-cage motor recently developed by the writer and which satisfies the conditions of high starting torque and low starting current in the line, is such that the rotor conductors have the inherent characteristic property of a relatively high resistance when alternating current of, say, 50 frequency, flows in them, whereas when the currents have the very low frequency corresponding to the rotor slip, the resistance will be practically the same as that given by direct current measurement. In other words, the inherent resistance of the rotor conductors is proportional to the frequency of the alternating current which flows in them.

When the motor starts, currents of the full supply frequency will flow in the rotor bars and the resistance of the rotor will therefore be automatically high, whereas when the rotor is running at full speed, the currents in the rotor winding will be of the very low frequency of slip and the resistance therefore will be low, and in fact, will be practically the same as that of a rotor of standard squirrel-cage construction. The conditions, therefore, are established for a high starting torque whilst at the same time the running characteristics of the motor are unimpaired. In order that the rotor bars may have the inherent characteristic property just described, a well known result in the theory of transformers has been utilised. This result may be stated as follows: If the secondary winding of a transformer is closed, the effective resistance of the primary winding to alternating currents is given by the expression*:—

$$R_1 + \frac{M^2 R_2 \omega^2}{(L_2\omega)^2 + R_2^2}$$

where R_1 ohms is the primary winding resistance when the secondary winding is open.
,, R_2 ohms is the resistance of the secondary circuit.
,, M is the coefficient of mutual induction of the windings.
,, L_2 is the coefficient of self-induction of the secondary winding.
,, ω is equal to 2π [frequency o the alternating current].

Fig. 2.

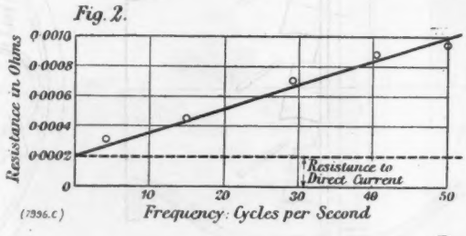
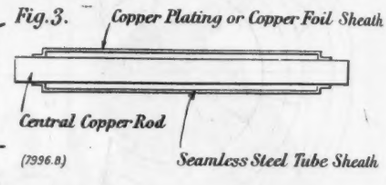
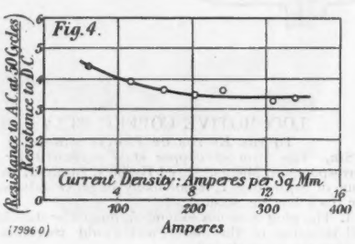


Fig. 3.





The effective inductance of the primary winding to alternating current, when the secondary circuit is closed, is:—

$$L_1 - \frac{M^2 L_2 \omega^2}{(L_2\omega)^2 + R_2^2}$$

where L_1 is the coefficient of self-induction of the primary winding.

An inspection of the foregoing formula for the resistance shows that, other things being equal, the effective resistance of the primary winding of a transformer of which the secondary winding is closed, is dependent on the frequency of the currents which flow in the primary winding. This result is the basic principle of the design of the new type of rotor conductors.

Perhaps the most obvious method of applying this principle is to construct each rotor conductor as illustrated in Fig. 1. As will be seen from the illustration, each conductor comprises a central copper rod which is surrounded by a seamless steel tube. The steel tube is coated with copper either in the form of copper foil, or electrolytically copper plated. Between the copper plated steel tube and the central copper rod is a layer of insulation. It will be obvious that the arrangement shown in Fig. 1 is a very simple form of transformer of which the central copper rod is the primary winding, the steel tube is the magnetic core, and the copper plating on the steel tube is the secondary winding. Hence, in accordance with the formula already given, if alternating current of various frequencies is supplied to the central copper rod, the effective resistance of this rod will increase with the frequency. In order to confirm that this theoretically deduced result is actually obtained tests were made on a rod of the following dimensions:—

Diameter of central copper rod ...	= 0·125 in.
Thickness of wall of seamless steel tube sheath	= 0·9 mm.
Thickness of copper plating on steel tube sheath	= 0·01 in.

The results of the test are shown in Fig. 2 from which it is seen that the effective resistance to alternating current is very approximately given by the relationship

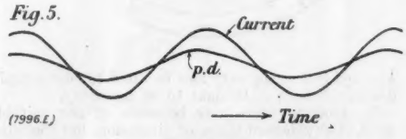
Resistance to a.c. = [Resistance to d.c.] × [1 + 0·06 (frequency)]

The tests also showed that the value of the power factor of this composite rod was practically unity at the higher values of the frequency, and this is an important characteristic of the device.*

Whilst the construction shown in Fig. 1 gives the desired result, it is not an ideal arrangement from a practical point of view. The inside covering of copper on the steel sheath is a little awkward to apply, and also the introduction of an insulating layer between the central copper rod and the plated steel sheath adds to the cost of construction. Further, the copper plating on the steel sheath is only effective during the starting period, and will not carry any appreciable current during the normal running period of the motor. This results in a relatively low value for the space factor for the rotor slots and, other things being equal, the size of the motor for a given output, when the construction shown in Fig. 1 is used, would have to be somewhat increased as compared with the size of a standard squirrel-cage motor. In this connection it is to be observed that the introduction of the steel sheath shown in Fig. 1 does not itself imply any appreciable reduction of the space factor, since this steel sheath is effective in carrying a portion of the main magnetic flux of the motor, so that the cross sectional area of the rotor teeth may be reduced by an amount corresponding to the cross sectional area of the steel sheath, without involving any appreciable increase of flux density in the rotor teeth.

In view of the foregoing consideration, the construction of the composite rotor bars has been very greatly simplified by forming them as *auto-transformers*, as shown in Fig. 3. This modified arrangement does not require any insulation layer, neither does it require any copper plating inside the steel sheath. As shown in Fig. 3, over the central copper rod is fitted the steel sheath (a seamless mild steel tube has been found to be very good material for this sheath). Copper plating is then provided over the outer surface of the steel tube, care being taken that this copper plating shall extend so as to make good electrical contact with each projecting end of the central copper rod.

Fig. 5.



One great advantage of the construction shown in Fig. 3 is that the copper plating is effective in carrying the rotor current during the normal running period. Hence the space factor of the rotor slots when such bars as shown in Fig. 3 are used, will be practically identically the same as when the standard rotor construction is employed. This leads to the important conclusion that a squirrel-cage motor built in accordance with this new design need not be any larger than a standard squirrel-cage motor for the same output.

In Fig. 4 are shown the results of some tests on a composite rod constructed as shown in Fig. 3. The data of the rod to which the results of Fig. 4 refer are as follows:—

Section of central copper core ...	17·5 sq. mms.
Thickness of steel sheath... ...	2·36 mms.
Thickness of outer copper foil sheath	0·01 in.

The results given in Fig. 4 show that the ratio

$$\frac{\text{Resistance to a.c. at 50 frequency}}{\text{Resistance to d.c.}} = 3{\cdot}4$$

for a wide range of current values.

In Fig. 5 is reproduced a representative oscillogram of the p.d. and current waves for a current of 202 amperes in the rod.

Numerical Example of the Performance of a Squirrel-cage Motor with Rotor Conductors constructed in accordance with the design shown in Fig. 3.—In a recent article† the writer has shown what proportional increase of rotor resistance is necessary to enable the motor to start with a given torque and with a given current in the line.

The same motor as considered in that article will be used for the purposes of the present example. The data of the motor are as follows:—

50 h.p.; 8 poles; 50 frequency; 3-phase star-connected stator; supply pressure 500 volts, that is, 289 volts per phase.

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* A paper read before Section G of the British Association at Liverpool, September, 1923.

† See A. Thomaelen, "Zur Geschichte des Induktionsmotors," E. T. Z., August 31, 1922, page 1105; L. Schueler, "Kurzschlussanker oder Schleifringanker?" E. T. Z., August 31, 1922, page 1108.

‡ See Journal of the Institution of Electrical Engineers, Vol. 61, page 128, January, 1923.

§ See T. F. Wall, ENGINEERING, August 10, 1923, page 164.

‖ See T. F. Wall, *Electrical Review*, July 13, page 44, August 10, 1923, page 208.

* See, for example, "Electrical Engineering," T. F. Wall, pages 434 and 464.

* See *Electrical Review*, ibid.

† See *Electrical Review*, *l.c.*, also ENGINEERING, *l.c.*

Resistance of the stator winding per phase	r_1	= 0·129 ohms.
Reactance of the stator winding per phase...	x_1	= 0·605 ohms.
Resistance of the standard rotor winding per phase when reduced to the stator number of turns	$r_2{}^1$	= 0·242 ohms.
Reactance of the standard rotor winding per phase when reduced to the stator number of turns and the stator frequency...	$x_2{}^1$	= 0·231 ohms.

$$\frac{\text{effective rotor resistance at starting}}{\text{effective rotor resistance at synchronous speed}}$$

when the supply pressure to the stator is reduced by means of an auto-transformer to (1/1·25) times the main supply pressure. It will be seen by reference to these figures that if the effective resistance of the rotor winding at starting is 3·4 times the rotor resistance at synchronous speed, the starting torque of the motor will be just over twice the full-load torque, and the starting current in the line will be 2·75 times the normal full-load current.

It is of interest to consider the torque-slip and the line current-slip curves of a squirrel-cage motor of which the rotor winding is formed of composite bars, as illustrated in Fig. 3. Assuming that the value of the reduced effective rotor resistance $R1_{2s}$ at any slip s is given by the expression (see Fig. 2)

$$R1_{2s} = r1_2 + (k - 1)\, r1_2\, s,$$

where $r1_2$ is the reduced effective rotor resistance when the rotor is running at synchronous speed, and

$$k = \frac{\text{effective rotor resistance at starting}}{\text{effective rotor resistance at synchronous speed}}$$

at starting, that is for $s = 1$, the expression reduces to

$$R1 = k \cdot r_2{}^1.$$

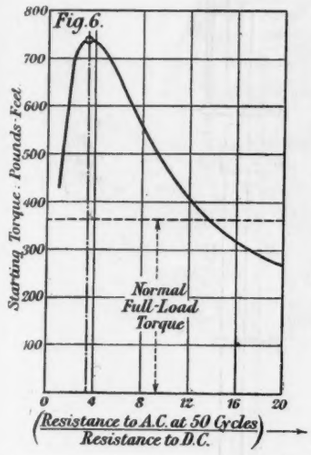
In Fig. 8 is given the torque-slip curve for the ratio $k = 3$, for the new type of rotor. For purposes of comparison the corresponding curve for the standard squirrel-cage rotor is shown also in Fig. 8. It will be observed that whilst the starting torque of the new type of rotor is about 1·7 times the starting torque of the standard rotor, the two curves fall into practical coincidence at about full-load conditions. In Fig. 9 are shown the line current-slip curves for both the standard squirrel-cage rotor and for the new type of rotor. Here again it will be observed that whilst for the new type of rotor the line current at starting is only 75 per cent. of that for the standard rotor, the two curves come into practical coincidence at about the full-load conditions. In Fig. 10 the torque-slip curves, and in Fig. 11 the line current-slip curves are shown when the stator pressure is reduced by means of an auto-transformer, the transformation ratio being 1 : 1·3. Another useful method of illustrating the results is given in Fig. 12. In this figure the starting torque and stator volts are shown as functions of the stator current for the following values of the ratio, k, viz., 1, 2, 3, 4.

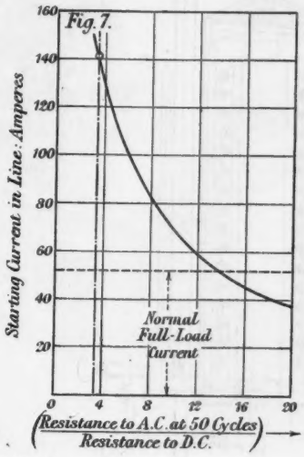
Conclusions.—The following is a summary of the advantages which may be expected from the new type of squirrel-cage motor as described in the foregoing, viz. :—

(1) High starting torque with low starting current in the line.

(2) Reduced cost as compared with the combination of a standard squirrel-cage motor and the necessary centrifugal clutch or other starting device to enable the standard squirrel-cage motor to start up light.

(3) Retains the inherent characteristic advantages of the standard squirrel-cage motor as compared with the slip-ring motor, amongst which are—(i) Absence of any possibility of sparking at the rotor and therefore permitting its use in explosive atmospheres. (ii) Reduced cost of upkeep due to absence of slip-rings and brushes. (iii) Increased efficiency. (iv) High power factor at full load.





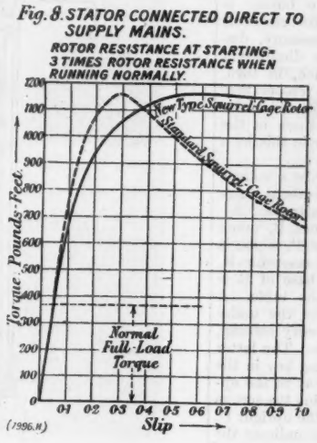


Fig. 8. STATOR CONNECTED DIRECT TO SUPPLY MAINS.
ROTOR RESISTANCE AT STARTING = 3 TIMES ROTOR RESISTANCE WHEN RUNNING NORMALLY.
New Type Squirrel-Cage Rotor
Standard Squirrel-Cage Rotor
Torque: Pounds-Feet
Normal Full-Load Torque
Slip

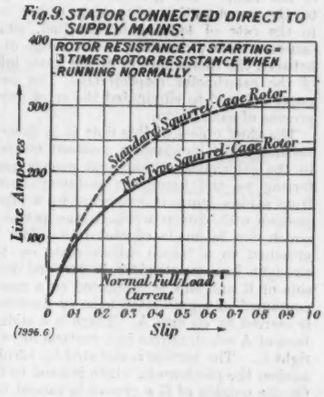


Fig. 9. STATOR CONNECTED DIRECT TO SUPPLY MAINS.
ROTOR RESISTANCE AT STARTING = 3 TIMES ROTOR RESISTANCE WHEN RUNNING NORMALLY.
Standard Squirrel-Cage Rotor
New Type Squirrel-Cage Rotor
Line Amperes
Normal Full-Load Current
Slip

$$\text{Transformer Ratio } \mu = \frac{\text{Main Supply Pressure}}{\text{Pressure Supplied to the Stator at Starting}} = 1{\cdot}25$$

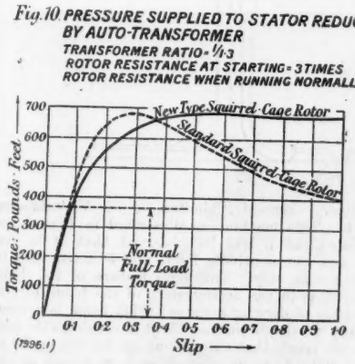


Fig. 10. PRESSURE SUPPLIED TO STATOR REDUCED BY AUTO-TRANSFORMER
TRANSFORMER RATIO = 1/1·3
ROTOR RESISTANCE AT STARTING = 3 TIMES ROTOR RESISTANCE WHEN RUNNING NORMALLY.
New Type Squirrel-Cage Rotor
Standard Squirrel-Cage Rotor
Torque: Pounds-Feet
Normal Full-Load Torque
Slip

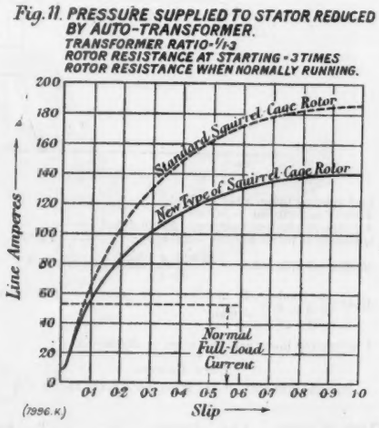
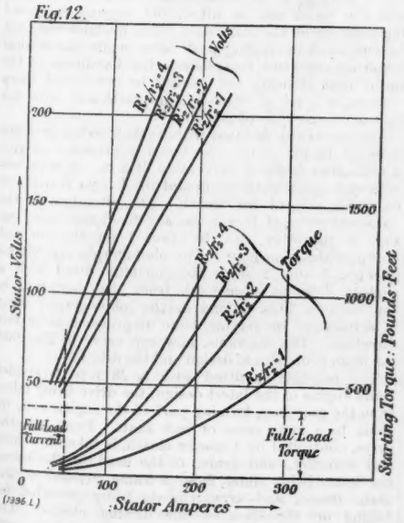


Fig. 11. PRESSURE SUPPLIED TO STATOR REDUCED BY AUTO-TRANSFORMER.
TRANSFORMER RATIO = 1/1·3
ROTOR RESISTANCE AT STARTING = 3 TIMES ROTOR RESISTANCE WHEN NORMALLY RUNNING.
Standard Squirrel-Cage Rotor
New Type of Squirrel-Cage Rotor
Line Amperes
Normal Full-Load Current
Slip



Reference to Fig. 4 shows that if the rotor rods are made in accordance with the data of the rod specified in connection with Fig. 3 the resistance of the rotor winding at starting will be about 3·4 times as large as the resistance when the rotor is running at full speed.

In Figs. 6 and 7 are given respectively the starting torque and the starting line current and functions of the ratio

ROYAL AIR FORCE CADETS.—The Air Ministry announces that an examination for the entry into the Royal Air Force of Cadets with a view to their becoming permanent commissioned officers after a two years' course at the Royal Air Force Cadet College, Cranwell, Lincolnshire, will be held on November 20 and following days. The closing date for entry for this examination is October 4, and no form of entry will be accepted under any circumstances after October 18. Applications should be made to the Secretary, Civil Service Commissioners, Burlington Gardens, W. 1 Candidates must be physically fit, and have attained the age of 17½, and not exceeded the age of 19 on January 1, 1924. The competition will be conducted in accordance with the regulations for the Royal Air Force (Cadet) College Air Publication 121, which may be obtained from H.M. Stationery Office, Imperial House, Kingsway, W.C. 2, price 9*d*.

TRACK-SHIFTING TROLLEY.—A rather unusual method of shifting tracks on dumps, excavations, &c., where frequent changes of lay and alignment are required as work progresses, has been developed by the Lake Superior Loader Company, Duluth, Minn., U.S.A. This firm have designed a motor trolley measuring about 10 ft. by 7 ft., and provided on either side between the wheels with a pair of claws which can be lowered to and made to grip the rails. The trolley is further provided with a spud fitted with a large flat-foot and worked by rack and pinion. This gear is arranged with lateral movement across the car, and when the track has to be slewed, the side grips are attached to the rails, the spud lowered on a slight slope and the whole trolley and track lifted by power derived from the trolley engine. In the course of the lift the whole outfit and track moves to one side, and by repeating the process a length of track can, it is claimed, be rapidly laid to new alignment, the trolley being moved along the line as necessary.

"FUTURE POSSIBILITIES OF AVIATION."—On Wednesday, the 19th inst., at the recent Shipping, Engineering and Machinery Exhibition at Olympia, a lecture bearing the title quoted above was delivered by Dr. A. P. Thurston under the auspices of the Institution of Aeronautical Engineers. The lecturer, after dealing with the part played by the aerial "taxi" and with some of the existing and proposed air routes, referred to the life of an aeroplane, stating that there were a number of machines in existence which had flown 400 hours to 500 hours and covered distances of from 40,000 miles to 50,000 miles without an overhaul. The future engine was considered in the light of past experience, and special attention was directed to the possibilities of the static radial type. After discussing the limiting size of aeroplanes, the lecturer stated that there appeared to be no insuperable difficulty in constructing machines weighing 100 tons each. He finally dealt with the possibilities of low-powered aeroplanes and exhibited a kinematograph film showing the "Wren" machine in flight. This machine weighs only 360 lb. in flying order and is driven by an A.B.C. motor-cycle engine rated at 3 h.p. Films of other machines and of an aerial combat were also shown.

THE DETERMINATION OF THE CALORIFIC VALUE OF LIQUID FUELS.

By NELSON HARWOOD, B.Sc. (Eng.) London, Burnley Municipal College.

THE various methods for the determination of the calorific value of fuels were discussed by Dr. Moss and Mr. Stern in the article published in ENGINEERING December 15, 1922, page 729. Of these methods the "Balance Method" was the one preferred by the authors. In this method the pressure necessary for supplying the fuel to the burner is obtained by pumping air into the petrol reservoir of the lamp. The gradual fall in air pressure, due to the consumption of petrol, causes a diminution in the rate of burning of the fuel, which, in turn, causes a steady decrease in the range of temperature between the thermometers at the water inlet and outlet of the calorimeter respectively. The authors of the paper referred to eliminated the error due to this by a process of calculation.

The chief object of this note is to describe a volume method which produces a constant temperature range in the calorimeter throughout each experiment. Referring to the figure, an ordinary burner B, taken from a blow lamp, is connected by a pipe P, which is packed with cotton wool, to the petrol reservoir R, which can be made of cast iron. The base of R is attached to a tripod which rests on the table. A wrought iron mouthpiece is screwed into the under side of R and this is connected to a mercury column, contained in a graduated tube or burette. The latter is carried by an arm A. There is a sliding key in the boss of A which moves in a vertical keyway in the upright U. The burette is elevated by turning the screws against the platform L, which is fixed to the upright U. On the outside of R a groove is turned to indicate the bottom of the reservoir. The platform and the parts attached to it are in some such position as L, initially. Mercury is poured into G to the level of the groove (the screwed plug C being removed from R). R is then filled with petrol or other liquid fuel to be tested. A joint of white lead is made at C. The burette is then filled with mercury and the platform is raised to give the pressure necessary to cause burning at the required rate. Mercury is added as required during heating of the calorimeter. The head of Mercury (h) necessary to keep the rate of burning steady and of the required amount is about 20 in. for petrol. A pointer P, attached to the upright, fixes the constant head, and the operator raises the graduated tube steadily by means of S, as the fuel is consumed. The difference between the initial and final readings on the burette opposite P is a measure of the number of cubic centimetres of petrol burned.

The apparatus described has been used in conjunction with the Simmance-Abady gas calorimeter, also shown in the sketch. This calorimeter works on the same principle as the Junker instrument, having a continuous flow of water, the quantity and rise in temperature of which are measured. A special supply of water was laid on, so that a constant rate of flow was obtained. This led to a constant temperature range, once a steady state had been attained. A steady state is necessary for both thermometers for, in comparing them with the standard, the writer observed appreciable time lags in following changes of temperature, such time lags being different for the different thermometers.

The chief fuels tested when using the blow lamp burner were petrol and benzine, about 30 experiments being performed with the former, and 20 with the latter. Alcohol proved difficult at first, but burned quite satisfactorily when a perforated cap was placed on top of the burner. A primus burner was used for testing paraffin oil.

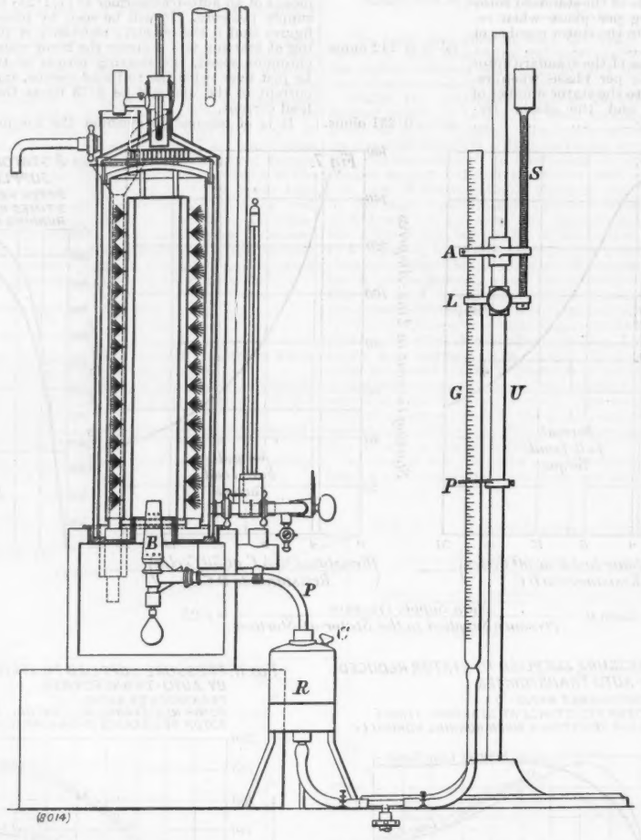
The apparatus is especially adapted for determining the most efficient rates of burning for the different fuels. The results obtained under the same pressure head are very consistent among themselves, although only about 20 c.c. were consumed during each test. (This of course is a larger amount than is usual with the balance method.) The variation in corresponding results is less than 1 per cent. Typical sets of readings are given below.

Aviation Petrol—Shell.

Specific gravity, 0·727 grms. per c.c. (at 15 deg. C.).
Observations taken every two minutes.

Temp. of Water.		Rise in Temp. (Deg. C.)	Circulating Water. (grms.)	Condensed Moisture. (grms.)	Temp. of Exhaust Gases. (Deg. C.)	Reading of Burette (C.C.)
Inlet. (Deg. C.)	Outlet. (Deg. C.)					
14	24·3	10·3	—	—	24·0	14·5
14	24·3	10·3	3,240	—	24·0	18·6
14	24·25	10·25	3,250	—	24·0	22·7
14	24·25	10·25	3,250	—	24·0	26·8
14	24·25	10·25	3,250	—	24·0	30·9
14	24·25	10·25	1,530	17·5	24·0	33·0

CALORIMETER FOR LIQUID FUEL.



Last reading taken after 1 minute.
Time of experiment = 540 secs.
Average rise in temperature = 10·26 deg. C.
Quantity of petrol burned = 18·5 × ·727 = 13·45 grms.

$$\text{Higher calorific value} = \frac{14{,}620 \times 10{\cdot}26}{13{\cdot}45} = 11{,}160 \text{ C.H.U.}$$

$$\text{Heat in condensed moisture per grm. of fuel burned} = \frac{17{\cdot}5 \times 616}{13{\cdot}45} = 800.$$

Uncorrected lower calorific value = 10,360 C.H.U.

Pure Benzene.

Specific gravity = 0·884 grms. per c.c. (at 15 deg. C.).

Temp. of Water.		Rise in Temp. (Deg. C.)	Circulating Water. (grms.)	Condensed Moisture. (grms.)	Temp. of Exhaust Gases. (Deg. C.)	Reading of Burette (C.C.)
Inlet. (Deg. C.)	Outlet. (Deg. C.)					
9·4	20·5	11·1	3,225	—	22·2	10·4
9·4	20·4	11·0	3,220	—	22·2	14·5
9·4	20·5	11·1	3,230	—	22·3	18·6
9·42	20·45	11·03	3,225	—	22·3	22·65
9·42	20·45	11·03	3,240	—	22·3	26·7
9·44	20·45	11·01	3,230	—	22·4	30·7
9·44	20·45	11·01	1,940	11·06	22·4	33·2

Last reading taken after 1 min. 15 secs.
Time of experiment = 675 secs.
Average rise in temp. = 11·04 deg. C.
Quantity of benzene burned = 22·8 × ·884 = 20·16 grms.

$$\text{Higher calorific value} = \frac{18{,}085 \times 11{\cdot}04}{20{\cdot}16} = 9{,}904 \text{ C.H.U.}$$

$$\text{Heat in condensed moisture for grm. of fuel burned} = \frac{11{\cdot}06 \times 617{\cdot}7}{20{\cdot}16} = 340 \text{ C.H.U.}$$

Uncorrected lower calorific value = 9,560 C.H.U.

These figures agree very closely with other uncorrected values previously published, and thereby justify the attempt to construct a volume apparatus which will withstand a fair amount of rough handling, is easy to make, and gives accurate results.

THE BARBER-GREENE VERTICAL BOOM TRENCH DIGGER.

A TYPE of trench-digging machine which presents several uncommon features has recently been developed by the Barber-Greene Company of Aurora, Ill., U.S.A., who are represented in this country by the Allied Machinery Company, Limited, of 70, Victoria-street, S.W.1. This machine is illustrated in Figs. 1 to 5 opposite, and it will be observed that it is compact and comparatively light, and is fitted with two chain tracks only. The main feature of the design, however, is in the arrangement of the boom carrying the chain of digging buckets. This boom is arranged to work vertically instead of at a considerable angle, with the result that excavation can be run to the full depth right up to an obstacle such as a rock or pipe, and the boom can be lifted, and digging continued immediately on the other side. The machine can even be employed in digging post holes, while the vertical boom arrangement so enhances the handiness of the outfit that trenches can readily be cut round sharp corners, a type of operation impracticable with the inclined boom type of machine.

This excavator is fitted with buckets to cut trenches 9 in. or 18 in. wide. The boom is arranged to give a maximum depth of excavation of 5 ft. A cross belt conveyor receives the spoil and discharges it well out on either side of the trench. The alteration of the cross conveyor, if it is necessary to change from one side to the other, can be effected on the job, and occupies about an hour. The photographs reproduced in Figs. 1 and 2 show the machine fitted with a slightly different framework from that indicated in the outlines Figs. 3 and 4, the photographs being of a machine embodying some improvements in this direction. The diagrams, however, serve to illustrate the main principles of design and the drives.

The machine is fitted with a 28 h.p. 4-cylinder Buda engine of the latest design, the drive being taken from the gear box, forming part of the engine unit, by chain to a main cross or jack shaft. From here the drive, controlled by a master clutch, is taken by chain and sprocket, and gears, to the head of the boom, the latter being slung from a frame pivoted to the main frame, and arrangements being provided for taking up the slack of the driving chains. The bucket chain is illustrated in Fig. 5, and is very ingenious in design. It is made self-clearing by forming the cast steel buckets of two pieces, so that, as each bucket passes over the top sprockets, the back of the bucket is broken and the contents are prised out. This device is said to be completely effective even in the stiffest clay. The digging lips are of manganese steel bolted to the lower section of the

VERTICAL BOOM TRENCH-DIGGER.

CONSTRUCTED BY THE BARBER-GREENE COMPANY, AURORA, ILL., U.S.A.

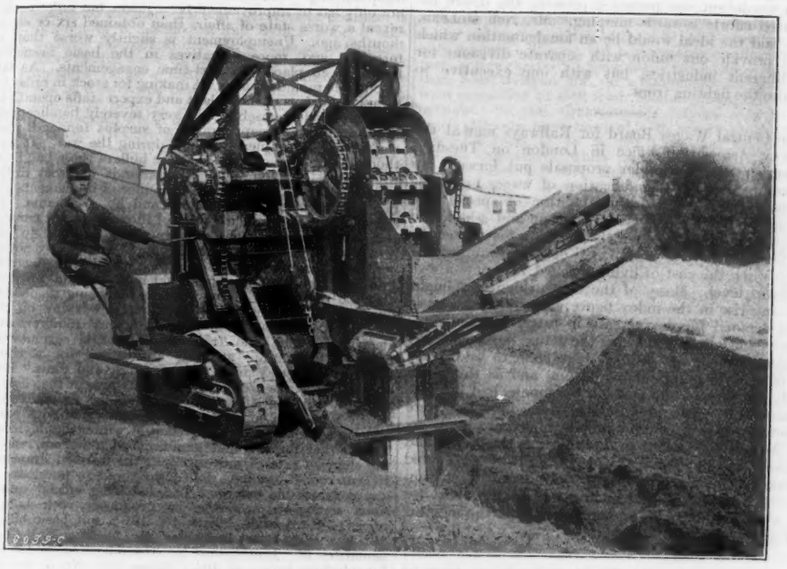


FIG. 1. MACHINE EXCAVATING TO FULL DEPTH.

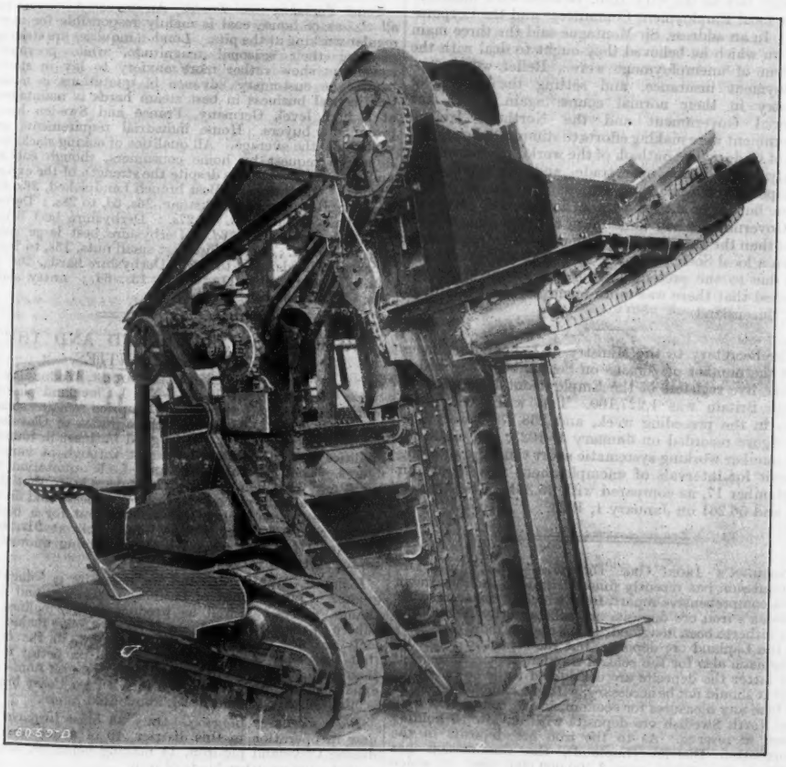
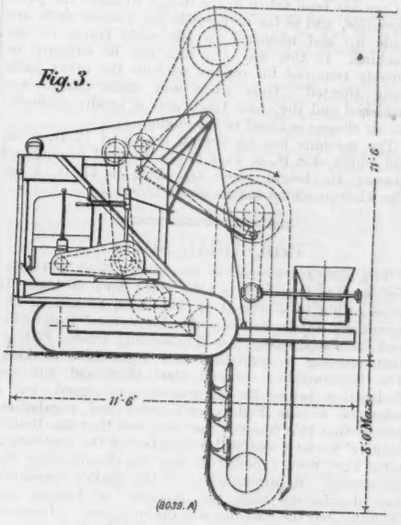
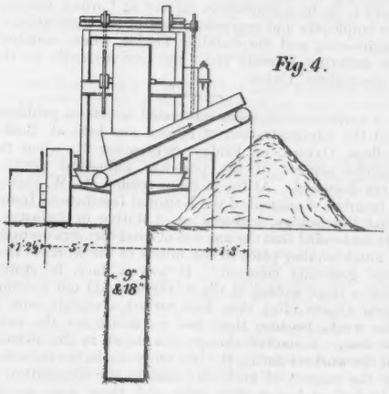
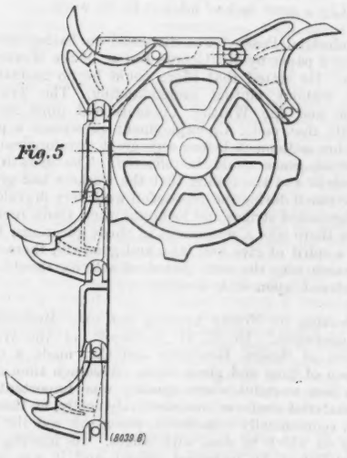


FIG. 2. MACHINE WITH BOOM RAISED.







buckets. The lips of alternate buckets are provided with two and three teeth respectively, the teeth having faces of about 2¼ in. The material discharged falls on to a belt conveyor as shown. This is driven by a chain and sprocket shown at the top of the digging boom, on the far side, in Fig. 1. A short cross shaft transmits this drive to the outside of the belt conveyor, where a chain and sprockets take it to the driving drum at the outboard end.

The digging boom is built up of plates and angles. The head and tail sprockets are centred 8 ft. 6 in. apart. The supporting arms embody a spring device to relieve the machine of shock, in case the buckets encounter an obstruction. The whole of the digging gear is lifted by power from the engine, by means of cables wound on to a drum which can be seen in Fig. 2 in the upper part of the main frame. The boom can be locked in any position for digging and is lowered by gravity. The bucket chain drive is fitted with a safety bolt which will fail if the buckets come to a dead stop against an obstruction, thus affording protection for the gear.

The chain tracks on which the machine is carried are self-cleaning, and 5 ft. long by 10 in. width of tread. The track frames are flexibly attached to the machine so that they can travel over rough ground. Three point suspension is secured by bolting the rear axle to the main frame and pivoting the front one. The drive provides three speeds for travelling from place to place, viz., 36 ft., 72 ft. and 144 ft. per minute, with a reverse of 42 ft. per minute. Steering is wholly by control of the drive to the track chains, which are for this reason worked by independent clutches on the jack shaft, controlled by separate hand levers, no differential being used. In addition to the travelling controls, others are arranged for use while digging,

which is accomplished at one or other of two speeds, according to the combination of sprockets, which can be readily changed to suit the conditions. These give digging speeds of 1 ft. and 5 ft. per minute. Steering while digging is also accomplished by means of the independent operation of the chain tracks.

Care has been taken in the design to make the parts accessible, and as far as possible the various units are made up and mounted on the main frame of the machine. In this way any unit can be adjusted or entirely removed for repairs without the other parts being affected. Gear cases and chain guards are furnished and the chain track gear is totally enclosed. An air cleaner is fitted to the engine.

The machine has an overall length of 13 ft. 6 in. and width of 8 ft. so that it can be used in confined spaces. Its height when travelling is 11 ft. 3 in. The whole machine weighs about 12,000 lb.

INDUSTRIAL NOTES.

THE shipyard lockout of the boilermakers and shipbuilders has now been in force since April 30 last. It arose owing to a refusal of the Union to honour the agreement made between the Employers' Federation and the Engineering and Shipbuilding Trades Federation relating to overtime and night-shift working. The Boilermakers contend that they had left the Federation before the agreement was signed, but a reference to the Federation's rules and regulations proves that this was not the case, and that the Boilermakers' Society was still a member of the Federation until they were expelled in May for dishonouring the agreement. Representatives of the parties concerned had discussions with the Minister of Labour last Monday, but the outcome was discouraging. However, there is to be a conference to-day at Carlisle between the employers and representatives of the Federation of Engineering and Shipbuilding Trades, whose members are suffering severely from the *intransigeance* of the Boilermakers' Union.

A conference of those interested in labour problems and the administration of labour was held at Balliol College, Oxford, on Friday, September 21, when the various aspects of the post-war industrial position were discussed. At the morning session Mr. W. Piercy, a member of council of the National Institute of Industrial Psychology, lectured on "Motive in Industry." He contended that the amount of total earnings occupied a much smaller place in the minds of the workers than was generally believed. It was a fact, he stated, that a large section of the workers would not continue their efforts after they had earned a certain sum in the week, because they had no desire for the extra income. A marked change was shown in the attitude of the workers during the last ten years in the reduction in the respect of authority and in the diminution of the fear of losing their jobs, and these were accompanied by a great lack of interest in the work.

"Industrial Peace" was discussed on Friday afternoon in a paper by Mr. George Dallas, of the Workers' Union. He stated that there could be no industrial peace without mutual understanding. The Trades Unions and the Whitley Councils had done much towards that end. Unemployment presented a problem for settlement before any great development of industrial peace could be effected. The growth of discontent and the feeling that the workers had given up too much during the depression were very prevalent. He forecasted strikes and lockouts when trade revives unless there was a settlement of these questions, but, with a spirit of give and take and goodwill, there was no reason why the next period of activity should not be entered upon with confidence.

Speaking on Friday evening last on "Methods of Remuneration," Dr. C. H. Northcott, of the Wages Section of Messrs. Rowntree and Co., made a comparison of time and piece rates. Although time rates were less wasteful where quality was important or the material used was comparatively costly, he thought that, economically considered, piecework was the best basis on which to deal with wages. Its introduction was followed by increased output, and it was much more simple and straightforward than the premium system in the eyes of the workmen. For the attainment of its full advantages the weaknesses of the system must be given close attention. The chief of these were the difficulties in fixing a fair basis of output, the bugbear of cutting rates and the absence of any guaranteed minimum. The system could not be used where the work was not standardised or where great care and attention were required in the work.

The triennial conference of delegates of the Workers' Union, which commenced with a private session on Sunday, was continued on Monday at Hampstead. Arising out of a discussion on the question of basing wages on the cost of living, the conference decided that it was not the best on which the workers should conclude wages agreements. There was a long discussion on the question of amalgamation of the various unions, and a resolution was passed expressing the desire for increased efforts towards merging. Mr. Neil McLean, M.P., said the ideal would be an amalgamation which would provide one union with separate divisions for the different industries, but with one executive to organise the fighting front.

The Central Wages Board for Railways met at the Railway Association office in London on Tuesday, September 25, to consider proposals put forward by the companies for a modification of wages and conditions. They included the abolition of special pay for night duty, Sunday labour at time and a-half, the introduction of a scheme of classification for enginemen and firemen, and the withdrawal of the remaining war bonus when the cost of living reached 70 points above the basis level. Many of the men evidently thought that any rise in the index figure was sufficient excuse for a demand for an increase in rates, but the companies issued a chart showing the actual position. The values at which the shilling wage changes take place are 65 and 75 points above datum, and as this accurately represented the position the unions had perforce to accept it. The proposals of the companies were objected to and counter-propositions were made by the Associated Society of Locomotive Engineers and Firemen, and the National Union of Railwaymen offered "uncompromising opposition." Under the circumstances a sitting of three hours was all too short for the accomplishment of an agreement, and the meeting was adjourned until October 10.

Sir Montague Barlow, Minister of Labour, when on a visit to Northern Ireland, had a conference on Tuesday last at the City Hall, Belfast, with members of the local Employment Committees and the Corporation. In an address, Sir Montague said the three main lines on which he believed they ought to deal with the problem of unemployment were: Relief works, unemployment insurance, and setting the wheels of industry in their normal course again. Both the Imperial Government and the Northern Ireland Government were making efforts to stimulate the normal flow of trade. The outlook of the world was not bright. Paralysis had fallen over trade, and the problem of unemployment was being experienced almost everywhere but in countries with a depreciated currency. No Governments had done more to relieve unemployment than the British and Northern Irish Governments. When a local Socialist leader said that unemployment was due to the present basis of society, Sir Montague retorted that there was more unemployment in Russia and Queensland.

The Secretary to the Ministry of Labour announces that the number of persons on September 17 recorded on the live registers of the Employment Exchanges in Great Britain was 1,227,100. This was 4,034 more than in the preceding week, and 258,778 fewer than the figure recorded on January 1, 1923. In addition, the number working systematic short time and drawing benefit for intervals of unemployment was 75,800 on September 17, as compared with 75,361 on September 10, and 56,261 on January 1, 1923.

SWEDEN'S IRON ORE DEPOSITS.—The State Ore Commission has recently finished its labours and drawn up a comprehensive report, from which it transpires that Sweden's iron ore deposits are substantially larger than has hitherto been imagined. This applies more especially to the Lapland ore deposits, but the report is decidedly optimistic also for the central Sweden area. As regards the latter the deposits are considered to be so extensive that it should not be necessary, within a calculable period, to take any measures for economising in connection with the North Swedish ore deposits with a view to holding them in reserve. As to the iron ore deposits in the Norrbotten District (Lapland), the Commission has arrived at a figure over 1,500,000,000 tons, of which comparatively large quantities are low in phosphorus. It is not considered economically feasible to transport the phosphoritic Lapland ores to the central Swedish iron works, nor will it as a rule be so with low phosphorus ores from the iron ore deposits belonging to the State. The Commission considers it impossible, from an economic point of view, to establish large iron works in Lapland for production either of pig-iron or finished products, and the State should not embark upon such an enterprise. The Commission considers that there does not appear to be any reason for limiting the export of the high phosphorus ore. On the contrary it would seem advisable to push this export as far as the conditions of the markets make it expedient. With regard to iron ores low in phosphor, the Commission does not express any opinion as to the desirability at present of the export of these ores being developed by the State or otherwise.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Generally speaking, conditions throughout the heavy steel industries are unsatisfactory. The rate of improvement experienced this year has been disappointing. Indeed, in some of the principal branches, not only has no improvement been made, but order books reveal a worse state of affairs than obtained six or eight months ago. Unemployment is slightly worse than a fortnight ago, more operatives in the basic branches having been placed on part-time engagements. As far as possible manufacturers are making for stock in order to keep the nucleus of their plant and expert staffs operative, but they find themselves still very severely handicapped by the repeated reappearance of surplus tonnages purchased on Government account during the war. It was thought three months ago that the bulk of these had been wiped out, but hundreds of thousands of twist drills, high-speed tools, saws, and all manner of implements are being offered at public auction and by merchants. So substantially is the selling price of these below the current cost of production, that manufacturers hesitate to put into reserve a larger tonnage than is covered by actual contract commitments. In the purely engineering branches conditions are somewhat more hopeful, but here also the percentage of inquiries materialising in definite business is insufficient to keep plant working on the average more than half time. Railway requirements, electrical orders, and tramway expansion schemes on British Corporation account are calling for a rising tonnage of special steels, steel fittings, and tools. Pick and shovel works are doing as well as any in the lighter sections, substantial orders being under execution for South Yorkshire collieries and in connection with road-making schemes for the provision of winter employment. The market for raw and semi-finished materials reflects the sluggish rate of movement in the finished branches. Recent reductions have failed to stimulate purchases to any considerable extent. The following official quotations represent, according to producers, rock bottom prices:—Hard basic billets, 10*l.* 10*s.*; soft basic billets, 8*l.* 15*s.*; West Coast hematites, 5*l.* 12*s.* 6*d.*; East Coast hematites, 5*l.*; Lincolnshire No. 3 foundry iron, 4*l.* 12*s.* 6*d.*; Lincolnshire forge, 4*l.* 10*s.*; Derbyshire No. 3 foundry iron, 4*l.* 12*s.* 6*d.*; Derbyshire forge, 4*l.* 10*s.*; bars, 12*l.*; sheets, 14*l.* to 15*l.*

South Yorkshire Coal Trade.—An increased demand for all classes of house coal is mainly responsible for more regular working at the pits. London inquiries are steadily reaching their seasonal magnitude, while provincial consumers show rather more anxiety to lay in stocks before the customary advance in quotations is made. Continental business in best steam hards is maintained at a high level, Germany, France and Sweden being prominent buyers. Home industrial requirements are well below the average. All qualities of coking slacks are in active request by home consumers, though cobbles and nuts show weakness despite the strength of the export inquiry. Quotations:—Best branch handpicked, 29*s.* 6*d.* to 31*s.*; Barnsley best Silkstone, 26*s.* 6*d.* to 28*s.*; Derbyshire best brights, 25*s.* to 27*s.*; Derbyshire best house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire best large nuts, 20*s.* to 21*s.* 6*d.*; Derbyshire best small nuts, 15*s.* to 16*s.*; Yorkshire hards, 21*s.* to 23*s.*; Derbyshire hards, 20*s.* to 22*s.*; rough slacks, 11*s.* 6*d.* to 13*s.* 6*d.*; nutty slack 10*s.* to 12*s.*; smalls, 7*s.* to 9*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—No. 1 Cleveland pig-iron continues extremely scarce, and its price remains steady and firm at 102*s.* 6*d.*; but other grades of Cleveland pig-iron are unsteady. Fairly good business in foundry qualities is said to have been put through at varying figures. The general f.o.t. and f.o.b. quotation for No. 3 may be given at 96*s.* 6*d.* Buyers state that they have been able to place orders at rather less, and on the other hand some makers are holding out for a higher price. No. 4 foundry is now obtainable at 91*s.* 6*d.*; and No. 4 forge at 89*s.* All the foregoing quotations are for early delivery.

Hematite.—Whilst demand for hematite is somewhat quieter, a fair amount of business is passing, and merchants, sellers, as well as producers, are inclined to adhere to the recently-advanced rates. Some makers, in fact, are not particularly pressing sales, in the belief that they may shortly be able to sell on better terms than are at present obtainable. The general home and export quotation for Nos. 1, 2 and 3 East Coast brands is 99*s.*, and No. 1 is put at 6*d.* above that figure.

Blast Furnaces Blowing.—Only 38 blast furnaces are now in operation in this district, 10 of which are producing Cleveland pig-iron, 11 making hematite, and 17 manufacturing other kinds of iron.

Foreign Ore.—There is little or nothing doing in imported ore, and market rates remain on the basis of 23*s.* c.i.f. Tees.

Manufactured Iron and Steel.—Most of the finished iron and steel manufacturers are short of work, and are keen to book orders. Slightly better accounts, however, are given of one or two departments, and hope is entertained that orders that have been held up will be released. Among the principal market quotations are:—Common iron bars, 12*l.*; iron rivets, 14*l.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; packing (parallel), 8*l.* 10*s.*; packing (tapered), 11*l.* 10*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge and tank plates, 9*l.* 15*s.*; angles, joists and heavy sections of steel rails, each 9*l.* 10*s.*; fish plates, 12*l.* 10*s.*; black sheets, 15*l.*; and galvanised corrugated sheets, 19*l.* 5*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Although the general trade position has not improved, there is to-day a brighter and more cheerful feeling due to the better reports about the Ruhr and the prospects that that great question is nearer solution. Another affair which is of very great importance to the steel trade of the West of Scotland is the lock-out of boilermakers, and it is a hopeful sign that another attempt to end the trouble is to be made on Friday of this week, at Carlisle, when representatives of both sides will be in conference. This meeting is the outcome of discussions between the Minister of Labour, Sir Montague Barlow, and representatives of all the parties concerned which took place in London on Monday of this week. If only this trouble were ended the shipbuilding yards would soon open up and the steel trade would gradually get better. In the meantime there is almost nothing doing in shipyard steel, and when any improvement will take place is a matter of some uncertainty. A bright spot at the moment is light sheets, and the black sheet makers are doing a tolerably good export trade just now, but the heavier gauges, especially for the home market, are in very poor demand still. Overall there is actually no change in the steel trade position this week, and prices remain steady at last week's quotations.

Malleable Iron Trade.—Depression is still prevalent in the malleable iron trade of the West of Scotland, and the outlook continues rather dark. Fresh business is not coming in with any regularity, and consumers are only buying small lots for immediate requirements, with the result that the majority of the works are only kept going from day to day. Inquiries are not very numerous and are mainly of small tonnage. Prices are unchanged, with "Crown" bars called 12*l.* per ton delivered Glasgow.

Scottish Pig-Iron Trade.—Movement in the Scottish pig-iron trade is still within narrow limits, and even the small output at the present time is more than sufficient to meet all demands. Hematite is in poor request, while foundry grades, although the subject of a better inquiry, are not moving at all freely. Quotations are without change at 5*l.* 5*s.* per ton for Scottish hematite, delivered at the steel works, and 5*l.* 5*s.* per ton for No. 1, and 5*l.* per ton for No. 3 foundry iron on trucks at makers' yards.

Shipments of Scottish Pig-Iron.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, September 22, amounted to 864 tons. Of that total 799 tons went foreign and 65 tons went coastwise. For the corresponding week of last year the figures were 1,417 tons 8 cwt. overseas and 40 tons coastwise, making a total shipment of 1,457 tons 8 cwt.

Wages in the Scottish Iron Trade Advanced.—Messrs. James C. Bishop and Owen Coyle, joint secretaries of the Scottish Manufactured Iron Trade Conciliation and Arbitration Board, have received the following intimation from Mr. John M. MacLeod, C.A., Glasgow: "In terms of the remit, I have examined the employers' books for July and August, 1923, and I certify that the average net selling price brought out is 12*l.* 2*s.* 10·3*d.* per ton." This means that there will be an increase in the wages of the workmen of 2½ per cent. on basis rates.

THE RAILWAY BRIDGE ACROSS THE LITTLE BELT.—The projected railway bridge across the Little Belt, between the island of Fuhnew and Jutland, which for a number of years has engaged the attention of the Danish State Railways, is still under consideration and is now in fact more likely to materialise than hitherto. Borings just completed have indicated excellent conditions. In the course of two months 13 different borings have been made. This is twice as many as in 1883 when a project put forward by the Director-General of the State Railways was examined. Besides being more numerous the recent borings have also been carried to a much greater depth than before, and the examination has revealed everywhere an excellent strata of blue clay. A few more borings have to be undertaken on the shore, on both sides, in order to ascertain the bearing power of the soil over these sections. The borings have not been confined merely to those requisite in connection with the bridge planned by the State railways, but also embraced work on the site of a private project for bridging the belt.

OXYGEN-OIL EXPLOSIONS.—A study of the nature and causes of oxygen-oil explosions is being conducted by the United States Department of the Interior at the Pittsburgh experiment station of the Bureau of Mines. This problem was taken up by the bureau as a result of the oxygen explosion at the Jefferson Physical Laboratory of Harvard University, and other similar explosions, in order to supply technical information which would serve as a basis for safety precautions in the future. At the Harvard inquiry the fact was emphasised that the limiting pressures and temperatures above which compressed oxygen and lubricating oil are capable of spontaneous explosion are not known. The problem is also of importance to the Army and Navy, and to the Bureau of Mines in connection with the hazards incurred in the use of compressed and liquefied gases in the repurification of helium. In fact, the risk of fires and explosions due to traces of lubricating oil coming into contact with high-pressure oxygen is of serious interest to all concerned with the manufacture and use of oxygen, a commodity which is now being produced and distributed on a rapidly increasing scale. A preliminary report, giving a general outline of the problem and a summary of results to date, is contained in Serial 2,507, by Mayo D. Hersey, physicist, which may be obtained from the Department of the Interior, Bureau of Mines, Washington, D.C.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The promise of an improvement in the coal trade which was suggested by the activity in chartering last week has not been maintained. A larger quantity of shipping than has been usual of late was fixed up, and it was thought that this would place collieries in a much more comfortable position. The heavy chartering certainly in individual cases considerably relieved collieries, but bad weather counteracted the more active chartering, for in many cases expected vessels have been delayed and, in consequence collieries have been compelled to seek fresh business to absorb current outputs. In the circumstances buyers able to take quick delivery have been able to secure their requirements at from 1*s.* to 2*s.* per ton below the ordinary market quotations, while prices vary considerably for similar classes of coal, being dependent on individual circumstances. Nominally, best Admiralty large is quoted at 28*s.* to 29*s.*, but supplies can be secured at 1*s.* less, while Monmouthshires rule from 26*s.* to 27*s.* 6*d.* and dry large from 27*s.* to 28*s.* Smalls of practically all descriptions continue in ample supply, with the best bunker sorts round 18*s.* and other grades from 13*s.* up, though coking smalls are steady at 22*s.* to 24*s.* Exports of coal as cargo last week according to the Custom's clearances amounted to 587,660 tons, of which 320,340 tons were despatched from Cardiff, 136,960 tons from Newport, 67,220 tons from Swansea, 49,310 tons from Port Talbot and 13,830 tons from Llanelly. Of the total shipments, France took 199,000 tons, Italy 104,720 tons, Argentina 53,200 tons, Egypt 31,400 tons, and 14,200 tons to the United States. The Danish State Railways are inviting tenders for 100,000 tons to 150,000 tons of Monmouthshire large coals for delivery over the nine months ending June next, while there are also inquiries from Portugal and Roumania for 20,000 tons each. The Swiss Federal Railways are also asking offers for 30,000 tons of patent fuel delivered up till the end of the year.

Iron and Steel.—In view of the decision to suspend import duties on goods for Japan, it is expected that there will be a good demand for galvanised sheets and certain specifications of tin-plates. In fact, inquiries are already circulating, and tin-plate prices are very firm at 23*s.* 1½*d.* to 23*s.* for boxes. Exports last week totalled only 7,944 tons compared with 13,852 tons in the previous week and 20,356 tons three weeks ago. Shipments of tin plates and terne plates amounted to 4,767 tons, compared with 5,861 tons, black plates and sheets to 365 tons against 3,776 tons, galvanised sheets to 1,858 tons against 2,092 tons, and other iron and steel goods to 954 tons against 2,123 tons.

Dredger Sunk at Cardiff.—The Cornish Salvage Company (1918), Limited, have secured the contract on a "no cure no pay" basis to raise the dredger The Duchess, which was sunk in the Roath Basin, Cardiff, a fortnight ago. The dredger, which lays in 35 ft. of water, has overturned, and her funnel and the top of the ladder is sticking in the bottom of the dock. It will be some months before she can be raised.

GERMANY'S FOREIGN TRADE.—The Commercial Secretary at Berlin (Mr. H. N. Sturrock) has forwarded to the Department of Overseas Trade an extract from the *Berliner Tageblatt*, of September 14, which states that, as a result of the continued occupation of the Customs Offices, the statistics of German foreign trade in July are again incomplete, as in the foregoing months. The following figures and comparisons must, therefore, be accepted with reserve:—

	Imports.		Exports.	
	July.	June.	July.	June.
	tons.	tons.	tons.	tons.
Total	4,159,600	4,806,600	1,054,000	889,700
Including—				
Food and drink ..	302,000	259,900	90,300	75,800
Raw materials and semi-manufactured goods ..	3,697,200	4,123,900	646,200	525,300
Finished goods ..	159,000	121,700	317,400	288,500

As before, the results of the occupation of the Ruhr are seen in the exceptionally large imports of coal and coke. For example, approximately 23,000,000 tons of pit coal—*i.e.*, more than double the monthly average of the previous year—were imported, so that the average of the seven months, January to June, 1923, is more than double the monthly average imports in 1922. In the case of coke the imports amounting to 190,000 tons have increased to nearly eight times the monthly average of 1922. The imports of iron ore have, however, declined further, namely, from 178,790 tons in June to 121,595 tons in July, less than one-seventh of the monthly average of 1922, which amounted to 917,810 tons. Some 69,793 tons of rolling-mill products and iron goods were exported in July, 59,170 tons in June, as compared with a monthly average of 193,015 tons in 1922. The exports of machinery were 27,622 tons in July, 18,247 tons in June, and a monthly average of 39,914 tons in 1922. The decline in production in the German iron and machinery industry is not less clearly illustrated by the fact that the imports of pig-iron and broken iron amounted, with 34,088 tons, to less than half the monthly average imports in 1922 (79,283 tons), while the exports amounted with 53,816 tons to more than double the average exports of 1922 (22,566 tons).

NOTICES OF MEETINGS.

THE SOCIETY OF ENGINEERS.—Monday, October 1, at 5.30 p.m., in the Rooms of the Geological Society, Burlington House, W., when a paper will be read on "Improved Method for Mass Production of Tank Glass Bottles, Jars, &c.," by Mr. Alec Ferguson, A.S.E.

THE INSTITUTE OF MARINE ENGINEERS, INCORPORATED.—Monday, October 1, at 6.30 p.m., at 85, The Minories, E. 1. Extraordinary General Meeting *re* Alterations to By-Laws.

THE INSTITUTE OF TRANSPORT.—Monday, October 1, at 5.30 p.m., in the Lecture Theatre, Institution of Electrical Engineers, Victoria Embankment, W.C. 2. Presidential Address by Sir J. G. Broodbank.

THE CERAMIC SOCIETY: REFRACTORY MATERIALS SECTION.—Thursday, October 4, at 10.30 a.m., in the Library, Grosvenor Museum, Chester. "General Sketch of the Geology of the Chester District," by Mr. T. Arthur Acton, F.S.A., F.G.S.; "Improvements in Drying Refractories or Other Goods," by Mr. J. Holland and Mr. W. J. Gardner; "The Zenith Temperature," by Mr. J. Whellor, D.Sc.; "Glass House Pots," by Mr. W. J. Rees, B.Sc. At 8 p.m., Dinner at Queen Hotel, Chester. Friday, October 5, at 11 a.m., in the Lecture Theatre, Grosvenor Museum, Chester. "Notes on the Proctor Dryer," by Mr. A. H. Middleton; "New Methods of Producing Gas for Industrial Operations," by Mr. R. Maclaurin; "The Effect of Salty Coal upon Refractory Materials," by Mr. L. M. Wilson, M.Sc.; "Carbonisation of Clay," by Mr. Walter Smith.

THE DIESEL ENGINE USERS ASSOCIATION.—Friday, October 5, at the Institution of Electrical Engineers, Savoy-place, Victoria Embankment, W.C. 2. Discussion on "Some Notes on a Broken Crankshaft and the Manner in which an Emergency Repair was carried out on a Diesel Engine in Barbados," and, if time permits, "Some Particulars of the Comparative Running Costs of Steam and Diesel Driven Pumping Plants in Alexandria, Egypt."

THE WEST YORKSHIRE METALLURGICAL SOCIETY.—Saturday, October 6, at 7 p.m., at the George Hotel, Huddersfield. Annual General Meeting.

THE INSTITUTE OF COST AND WORKS ACCOUNTANTS.—The headquarters of this Institute have been moved to 6, Duke-street, St. James', London, S.W. 1.

PROPOSED MERSEY TUNNEL.—With a view to improving communication between Liverpool and Birkenhead, the proposal has been put forward to construct a tunnel under the Mersey. The subject has been considered by experts, and at a meeting of the Merseyside Co-ordination Committee held on Wednesday last, Sir Archibald Salvidge explained that a bridge was out of the question for financial reasons, and that a 44 ft. tunnel could, according to estimates, be constructed for about 4,000,000*l.* less. The tunnel would have two branch outlets on each side of the river. As the tunnel would have a national value from the highway point of view the Government is to be approached with regard to a grant for the scheme, which it is pointed out would also provide useful work for the unemployed.

CARBON TETRACHLORIDE FIRE EXTINGUISHERS.—Tests made by the United States Department of the Interior at the Pittsburgh experiment station of the Bureau of Mines relative to the hazards to fire fighters from gases and smoke resulting from the application of carbon tetrachloride extinguisher to electric arcs, burning insulation, or fires such as may occur in electrical apparatus and machinery, are summarised in a serial just issued by the Department. It was found that the application of 1 cub. ft. of carbon tetrachloride fire extinguisher to electric arcs and burning insulation in a chamber of 1,000 cub. ft. capacity, developed phosgene, chlorine and hydrogen chloride in quite dangerous concentrations. Carbon tetrachloride vapours, sulphur dioxide and carbon monoxide were also formed in less dangerous concentrations. Rats exposed for 15-minute periods to the gases evolved from the use of carbon tetrachloride on the arcs died or were seriously affected. These tests confirm conclusions drawn from previous tests by the Bureau of Mines that it is dangerous to breathe the gases that may be generated from 1 quart of carbon tetrachloride extinguisher applied to a fire in a confined space from which escape is difficult or impossible, and from which the gases would not be removed by ventilation. So far as is known, carbon tetrachloride extinguishers are the most effective and satisfactory of any that can be applied to electrical fires with safety from shock to the operator. Arcs of 60 amperes direct current and 220 volts, and 35 amperes and 500 volts, were easily extinguished with a 1-quart carbon tetrachloride fire extinguisher. The purpose of these experiments of the Bureau of Mines was to determine the extent of the danger from poisonous gases arising from use of carbon tetrachloride extinguisher on electrical fires, and to promote safety of fire-fighters through their knowledge of those conditions. It is not the purpose to discourage the use of carbon tetrachloride extinguishers, which are safe under all conditions, excepting those of close confinement of fire gases in absence of ventilation, and lack of ready escape for the operator from the gases. Such conditions may occur in unventilated parts of mines, vaults and cellars. They do not usually exist in buildings or the entries of mines where electric locomotives are used for hauling, since these customarily are well ventilated.

REINFORCED CONCRETE BRIDGE ACROSS THE RIVER THAMES AT READING.

CONSTRUCTED TO THE DESIGNS OF MESSRS. L. G. MOUCHEL AND PARTNERS, LIMITED, ENGINEERS, WESTMINSTER.

(*For Description, see Page* 385.)

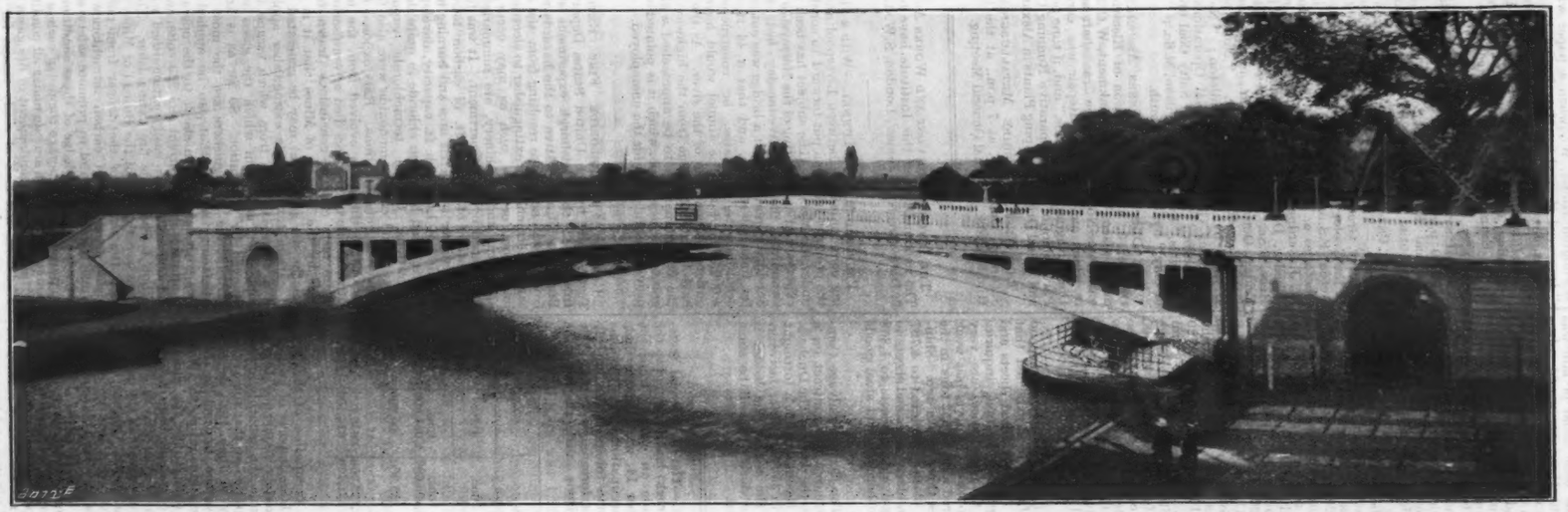


FIG. 21. GENERAL VIEW OF COMPLETED BRIDGE.

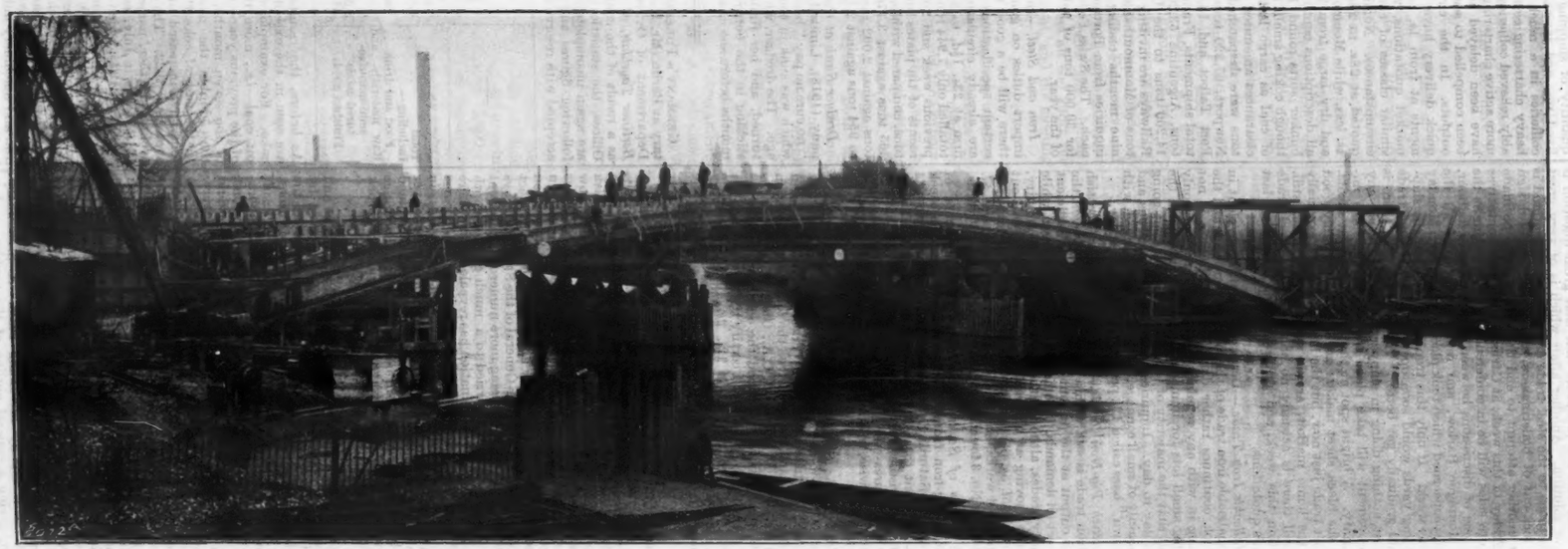


FIG. 22. VIEW OF MAIN SPAN DURING CONSTRUCTION, SHOWING SUPPORT OF SHUTTERING.

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REINFORCED CONCRETE BRIDGE ACROSS THE RIVER THAMES AT READING.

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(For Description, see Page 385.)

Fig. 3. EAST ELEVATION OF BRIDGE.

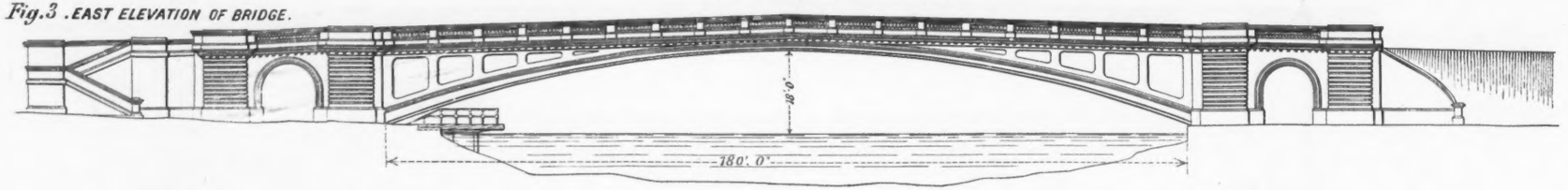


Fig. 4. WEST ELEVATION OF VIADUCT AND APPROACH.

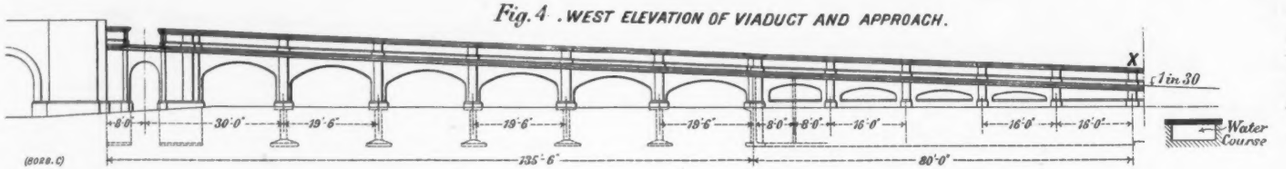


Fig. 5. ELEVATION OF SPUR.

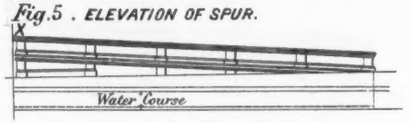


Fig. 6. LONGITUDINAL SECTION ON LINE G.G.

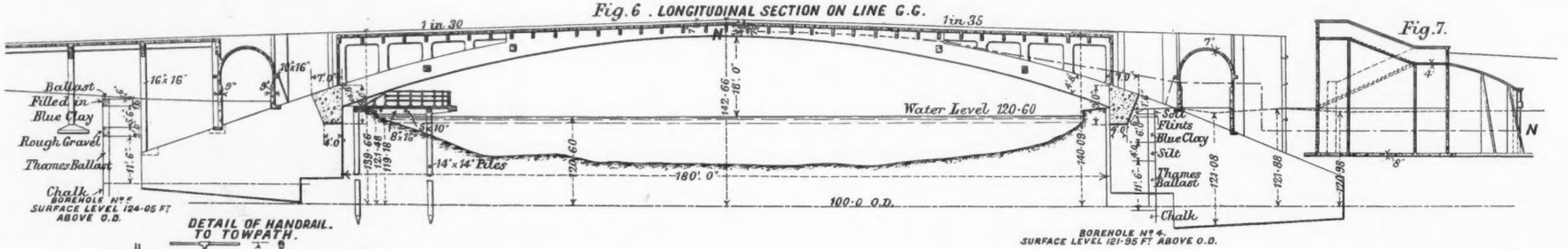


Fig. 7.

DETAIL OF HANDRAIL TO TOWPATH.

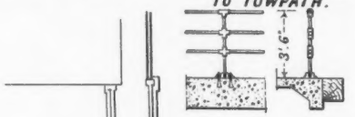
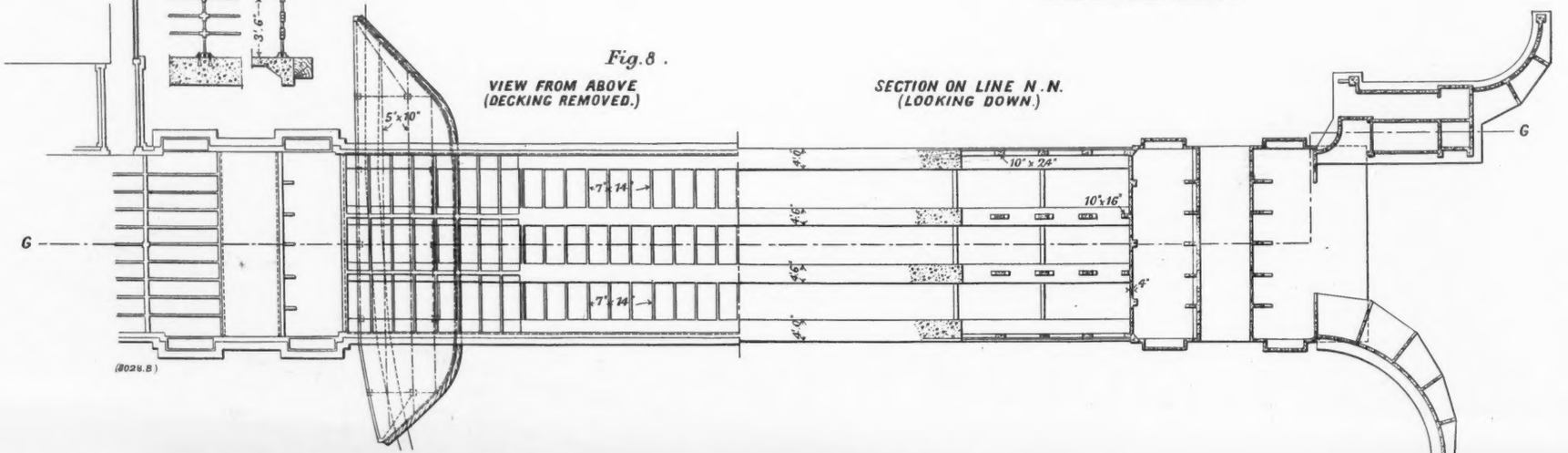


Fig. 8.

VIEW FROM ABOVE (DECKING REMOVED.)

SECTION ON LINE N.N. (LOOKING DOWN.)



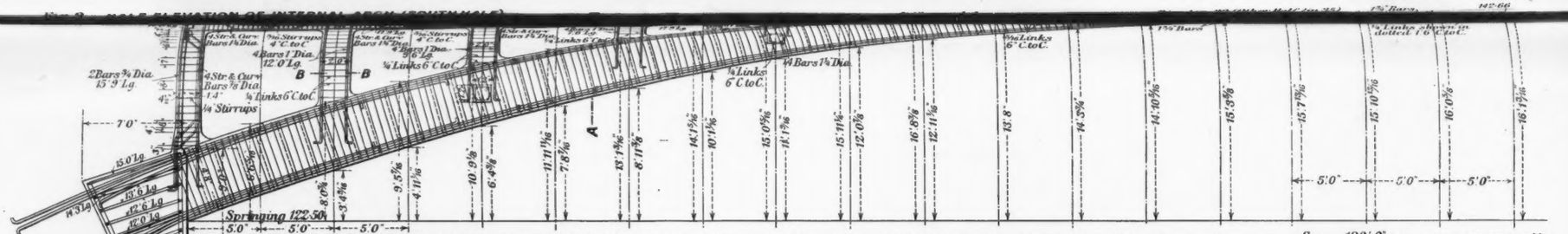


Fig. 10. SECTION THRO' DECKING

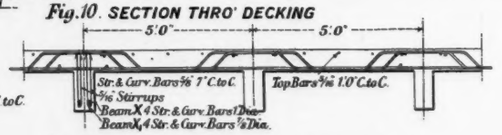


Fig. 11. HALF CROSS SECTION ON A.A.

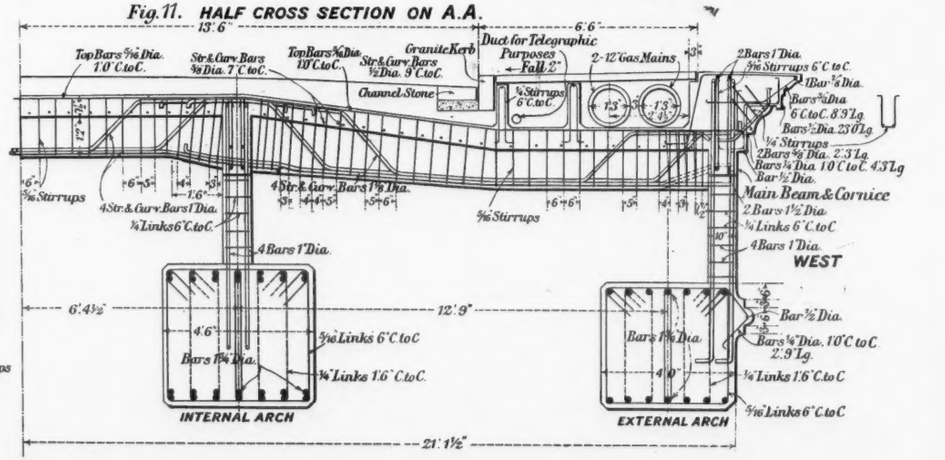

13'6"
6'6"
Top Bars ⅞ Dia. 1'0" C. to C.
Str. & Curv. Bars ⅝ Dia. 7" C. to C.
Top Bars ⅞ Dia. 10" C. to C.
Str. & Curv. Bars ½ Dia. 9" C. to C.
Granite Kerb
Channel Stone
Duct for Telegraphic Purposes ← Fall 2"
2-12" Gas Mains
2 Bars 1" Dia.
⅝ Stirrups 6" C. to C.
1 Bar ⅞ Dia.
Bars ⅞ Dia. 6" C. to C. 8'3" Lg.
Bars ½ Dia. 23'0" Lg.
⅝ Stirrups
2 Bars ⅝ Dia. 2'3" Lg.
Bars ¾ Dia. 1'0" C. to C. 4'3" Lg.
Bar ½ Dia.
Main Beam & Cornice
2 Bars 1½ Dia.
¾ Links 6" C. to C.
4 Bars 1" Dia.
WEST
4 Str. & Curv. Bars 1" Dia.
¼ Links 6" C. to C.
⅝ Stirrups
6'4½"
12'9"
4 Bars 1" Dia.
4'6"
Bars 1¾ Dia.
⅝ Links 6" C. to C.
¾ Links 1'6" C. to C.
INTERNAL ARCH
Bars 1¾ Dia.
4'0"
Bar ½ Dia.
Bars ¾ Dia. 1'0" C. to C. 2'9" Lg.
¾ Links 1'6" C. to C.
⅝ Links 6" C. to C.
EXTERNAL ARCH
21'1½"

Fig. 12. HALF CROSS SECTION AT CENTRE

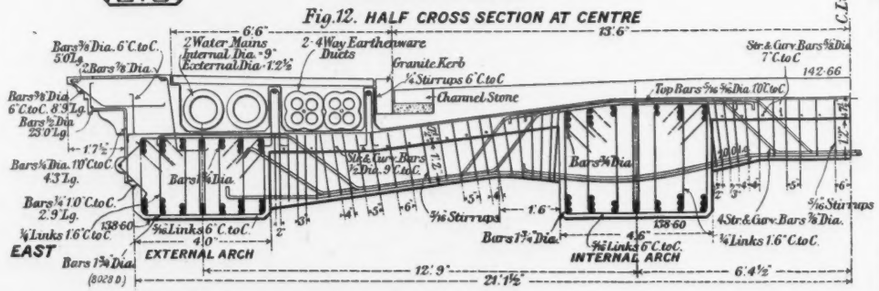

6'6"
13'6"
2 Water Mains Internal Dia. 9" External Dia. 12½"
2-4 Way Earthenware Ducts
Granite Kerb
¾ Stirrups 6" C. to C.
Channel Stone
Top Bars ⅞ to ⅝ Dia. 10" C. to C.
Str. & Curv. Bars ⅝ Dia. 7" C. to C.
142·66
C. Line
Bars ⅜ Dia. 6" C. to C. 5'0" Lg.
2 Bars ⅜ Dia.
Bars ⅜ Dia. 6" C. to C. 8'3" Lg.
Bars ½ Dia. 23'0" Lg.
Bars ¾ Dia. 10" C. to C. 4'3" Lg.
Bars ¾ 10" C. to C. 2'9" Lg.
¾ Links 1'6" C. to C.
⅝ Links 6" C. to C.
⅝ Stirrups
Str. & Curv. Bars ½ Dia. 9" C. to C.
Bars ¾ Dia.
Bars 1¾ Dia.
138·60
4'0"
EAST
EXTERNAL ARCH
INTERNAL ARCH
4 Str. & Curv. Bars ⅞ Dia.
12'9"
6'4½"
21'1½"

Fig. 13. SOUTH ABUTMENT.

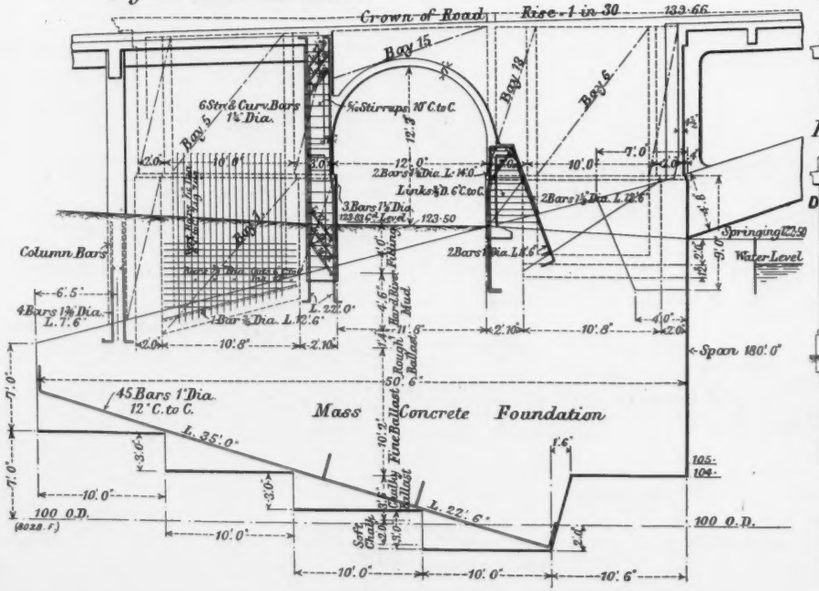


Fig. 14. HALF CROSS SECTION SHOWING DECKING.

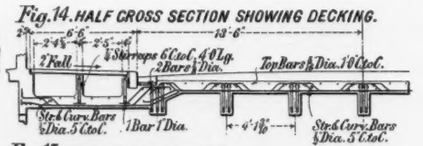

13'6"
2 Fall
¾ Stirrups 6" C. to C. 4'0" Lg.
2 Bars ⅞ Dia.
Top Bars ⅞ Dia. 1'0" C. to C.
Str. & Curv. Bars ⅝ Dia. 5" C. to C.
1 Bar 1" Dia.
Str. & Curv. Bars ⅝ Dia. 5" C. to C.

Fig. 15. ELEVATION OF BEAM G.

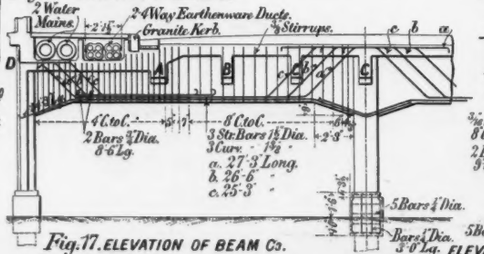
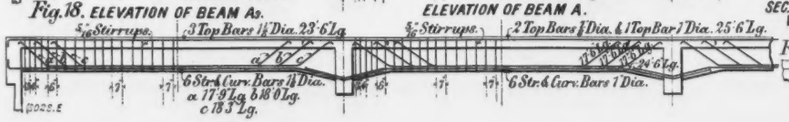


Fig. 17. ELEVATION OF BEAM C3.

Fig. 18. ELEVATION OF BEAM A3.



DETAILS OF APPROACH VIADUCT

SECTION Y.Y. (Fig. 16.)

BEAMS E & E1.

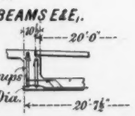
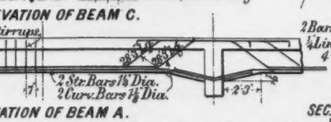


Fig. 16. OUTSIDE ELEVATION.

Bars 1" Dia. 23'6" Lg.
¼ Links 8" C. to C.
1 Bar 1" Dia. 22'8" Lg.
3 Bars 1" Dia. 23'6" Lg.
4 Links 8" C. to C.
2 Bars ⅝ Dia. 11'0" Lg.
2 Bars ⅝ Dia. 9'6" Lg.
2 Bars ⅝ Dia. 3'6" Lg.
2 Bars ⅝ Dia. 9'6" Lg.
¼ Links 8" C. to C.
Bars ¼ Dia. 8" C. to C.
2 Bars ⅝ Dia. 10'0" Lg.
5 Bars ¼ Dia.
Bars ¼ Dia. 3'0" Lg.

ELEVATION OF BEAM C.



ELEVATION OF BEAM A.

BEAM D.

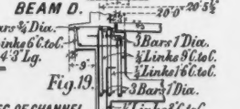


Fig. 19.

SEC. OF CHANNEL WEST SIDE.

Fig. 20.

which is accomplished at one or other of two speeds, according to the combination of sprockets, which can be readily changed to suit the conditions. These give digging speeds of 1 ft. and 5 ft. per minute. Steering while digging is also accomplished by means of the independent operation of the chain tracks.

Care has been taken in the design to make the parts accessible, and as far as possible the various units are made up and mounted on the main frame of the machine. In this way any unit can be adjusted or entirely removed for repairs without the other parts being affected. Gear cases and chain guards are furnished and the chain track gear is totally enclosed. An air cleaner is fitted to the engine.

The machine has an overall length of 13 ft. 6 in. and width of 8 ft. so that it can be used in confined spaces. Its height when travelling is 11 ft. 3 in. The whole machine weighs about 12,000 lb.

INDUSTRIAL NOTES.

THE shipyard lockout of the boilermakers and shipbuilders has now been in force since April 30 last. It arose owing to a refusal of the Union to honour the agreement made between the Employers' Federation and the Engineering and Shipbuilding Trades Federation relating to overtime and night-shift working. The Boilermakers contend that they had left the Federation before the agreement was signed, but a reference to the Federation's rules and regulations proves that this was not the case, and that the Boilermakers' Society was still a member of the Federation until they were expelled in May for dishonouring the agreement. Representatives of the parties concerned had discussions with the Minister of Labour last Monday, but the outcome was discouraging. However, there is to be a conference to-day at Carlisle between the employers and representatives of the Federation of Engineering and Shipbuilding Trades, whose members are suffering severely from the *intransigeance* of the Boilermakers' Union.

A conference of those interested in labour problems and the administration of labour was held at Balliol College, Oxford, on Friday, September 21, when the various aspects of the post-war industrial position were discussed. At the morning session Mr. W. Piercy, a member of council of the National Institute of Industrial Psychology, lectured on "Motive in Industry." He contended that the amount of total earnings occupied a much smaller place in the minds of the workers than was generally believed. It was a fact, he stated, that a large section of the workers would not continue their efforts after they had earned a certain sum in the week, because they had no desire for the extra income. A marked change was shown in the attitude of the workers during the last ten years in the reduction in the respect of authority and in the diminution of the fear of losing their jobs, and these were accompanied by a great lack of interest in the work.

"Industrial Peace" was discussed on Friday afternoon in a paper by Mr. George Dallas, of the Workers' Union. He stated that there could be no industrial peace without mutual understanding. The Trades Unions and the Whitley Councils had done much towards that end. Unemployment presented a problem for settlement before any great development of industrial peace could be effected. The growth of discontent and the feeling that the workers had given up too much during the depression were very prevalent. He forecasted strikes and lockouts when trade revives unless there was a settlement of these questions, but, with a spirit of give and take and goodwill, there was no reason why the next period of activity should not be entered upon with confidence.

Speaking on Friday evening last on "Methods of Remuneration," Dr. C. H. Northcott, of the Wages Section of Messrs. Rowntree and Co., made a comparison of time and piece rates. Although time rates were less wasteful where quality was important or the material used was comparatively costly, he thought that, economically considered, piecework was the best basis on which to deal with wages. Its introduction was followed by increased output, and it was much more simple and straightforward than the premium system in the eyes of the workmen. For the attainment of its full advantages the weaknesses of the system must be given close attention. The chief of these were the difficulties in fixing a fair basis of output, the bugbear of cutting rates and the absence of any guaranteed minimum. The system could not be used where the work was not standardised or where great care and attention were required in the work.

The triennial conference of delegates of the Workers' Union, which commenced with a private session on Sunday, was continued on Monday at Hampstead. Arising out of a discussion on the question of basing wages on the cost of living, the conference decided that it was not the best on which the workers should conclude wages agreements. There was a long discussion on the question of amalgamation of the various unions, and a resolution was passed expressing the desire for increased efforts towards merging. Mr. Neil McLean, M.P., said the ideal would be an amalgamation which would provide one union with separate divisions for the different industries, but with one executive to organise the fighting front.

The Central Wages Board for Railways met at the Railway Association office in London on Tuesday, September 25, to consider proposals put forward by the companies for a modification of wages and conditions. They included the abolition of special pay for night duty, Sunday labour at time and a-half, the introduction of a scheme of classification for enginemen and firemen, and the withdrawal of the remaining war bonus when the cost of living reached 70 points above the basis level. Many of the men evidently thought that any rise in the index figure was sufficient excuse for a demand for an increase in rates, but the companies issued a chart showing the actual position. The values at which the shilling wage changes take place are 65 and 75 points above datum, and as this accurately represented the position the unions had perforce to accept it. The proposals of the companies were objected to and counter-propositions were made by the Associated Society of Locomotive Engineers and Firemen, and the National Union of Railwaymen offered "uncompromising opposition." Under the circumstances a sitting of three hours was all too short for the accomplishment of an agreement, and the meeting was adjourned until October 10.

Sir Montague Barlow, Minister of Labour, when on a visit to Northern Ireland, had a conference on Tuesday last at the City Hall, Belfast, with members of the local Employment Committees and the Corporation. In an address, Sir Montague said the three main lines on which he believed they ought to deal with the problem of unemployment were: Relief works, unemployment insurance, and setting the wheels of industry in their normal course again. Both the Imperial Government and the Northern Ireland Government were making efforts to stimulate the normal flow of trade. The outlook of the world was not bright. Paralysis had fallen over trade, and the problem of unemployment was being experienced almost everywhere but in countries with a depreciated currency. No Governments had done more to relieve unemployment than the British and Northern Irish Governments. When a local Socialist leader said that unemployment was due to the present basis of society, Sir Montague retorted that there was more unemployment in Russia and Queensland.

The Secretary to the Ministry of Labour announces that the number of persons on September 17 recorded on the live registers of the Employment Exchanges in Great Britain was 1,227,100. This was 4,034 more than in the preceding week, and 258,778 fewer than the figure recorded on January 1, 1923. In addition, the number working systematic short time and drawing benefit for intervals of unemployment was 75,800 on September 17, as compared with 75,361 on September 10, and 56,261 on January 1, 1923.

SWEDEN'S IRON ORE DEPOSITS.—The State Ore Commission has recently finished its labours and drawn up a comprehensive report, from which it transpires that Sweden's iron ore deposits are substantially larger than has hitherto been imagined. This applies more especially to the Lapland ore deposits, but the report is decidedly optimistic also for the central Sweden area. As regards the latter the deposits are considered to be so extensive that it should not be necessary, within a calculable period, to take any measures for economising in connection with the North Swedish ore deposits with a view to holding them in reserve. As to the iron ore deposits in the Norrbotten District (Lapland), the Commission has arrived at a figure over 1,500,000,000 tons, of which comparatively large quantities are low in phosphorus. It is not considered economically feasible to transport the phosphoritic Lapland ores to the central Swedish iron works, nor will it as a rule be so with low phosphorus ores from the iron ore deposits belonging to the State. The Commission considers it impossible, from an economic point of view, to establish large iron works in Lapland for production either of pig-iron or finished products, and the State should not embark upon such an enterprise. The Commission considers that there does not appear to be any reason for limiting the export of the high phosphorus ore. On the contrary it would seem advisable to push this export as far as the conditions of the markets make it expedient. With regard to iron ores low in phosphor, the Commission does not express any opinion as to the desirability at present of the export of these ores being developed by the State or otherwise.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Generally speaking, conditions throughout the heavy steel industries are unsatisfactory. The rate of improvement experienced this year has been disappointing. Indeed, in some of the principal branches, not only has no improvement been made, but order books reveal a worse state of affairs than obtained six or eight months ago. Unemployment is slightly worse than a fortnight ago, more operatives in the basic branches having been placed on part-time engagements. As far as possible manufacturers are making for stock in order to keep the nucleus of their plant and expert staffs operative, but they find themselves still very severely handicapped by the repeated reappearance of surplus tonnages purchased on Government account during the war. It was thought three months ago that the bulk of these had been wiped out, but hundreds of thousands of twist drills, high-speed tools, saws, and all manner of implements are being offered at public auction and by merchants. So substantially is the selling price of these below the current cost of production, that manufacturers hesitate to put into reserve a larger tonnage than is covered by actual contract commitments. In the purely engineering branches conditions are somewhat more hopeful, but here also the percentage of inquiries materialising in definite business is insufficient to keep plant working on the average more than half time. Railway requirements, electrical orders, and tramway expansion schemes on British Corporation account are calling for a rising tonnage of special steels, steel fittings, and tools. Pick and shovel works are doing as well as any in the lighter sections, substantial orders being under execution for South Yorkshire collieries and in connection with road-making schemes for the provision of winter employment. The market for raw and semi-finished materials reflects the sluggish rate of movement in the finished branches. Recent reductions have failed to stimulate purchases to any considerable extent. The following official quotations represent, according to producers, rock bottom prices:—Hard basic billets, 10*l.* 10*s.*; soft basic billets, 8*l.* 15*s.*; West Coast hematites, 5*l.* 12*s.* 6*d.*; East Coast hematites, 5*l.*; Lincolnshire No. 3 foundry iron, 4*l.* 12*s.* 6*d.*; Lincolnshire forge, 4*l.* 10*s.*; Derbyshire No. 3 foundry iron, 4*l.* 12*s.* 6*d.*; Derbyshire forge, 4*l.* 10*s.*; bars, 12*l.*; sheets, 14*l.* to 15*l.*

South Yorkshire Coal Trade.—An increased demand for all classes of house coal is mainly responsible for more regular working at the pits. London inquiries are steadily reaching their seasonal magnitude, while provincial consumers show rather more anxiety to lay in stocks before the customary advance in quotations is made. Continental business in best steam hards is maintained at a high level, Germany, France and Sweden being prominent buyers. Home industrial requirements are well below the average. All qualities of coking slacks are in active request by home consumers, though cobbles and nuts show weakness despite the strength of the export inquiry. Quotations:—Best branch handpicked, 29*s.* 6*d.* to 31*s.*; Barnsley best Silkstone, 26*s.* 6*d.* to 28*s.*; Derbyshire best brights, 25*s.* to 27*s.*; Derbyshire best house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire best large nuts, 20*s.* to 21*s.* 6*d.*; Derbyshire best small nuts, 15*s.* to 16*s.*; Yorkshire hards, 21*s.* to 23*s.*; Derbyshire hards, 20*s.* to 22*s.*; rough slacks, 11*s.* 6*d.* to 13*s.* 6*d.*; nutty slack 10*s.* to 12*s.*; smalls, 7*s.* to 9*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—No. 1 Cleveland pig-iron continues extremely scarce, and its price remains steady and firm at 102*s.* 6*d.*; but other grades of Cleveland pig-iron are unsteady. Fairly good business in foundry qualities is said to have been put through at varying figures. The general f.o.t. and f.o.b. quotation for No. 3 may be given at 96*s.* 6*d.* Buyers state that they have been able to place orders at rather less, and on the other hand some makers are holding out for a higher price. No. 4 foundry is now obtainable at 91*s.* 6*d.*; and No. 4 forge at 89*s.* All the foregoing quotations are for early delivery.

Hematite.—Whilst demand for hematite is somewhat quieter, a fair amount of business is passing, and merchants, sellers, as well as producers, are inclined to adhere to the recently-advanced rates. Some makers, in fact, are not particularly pressing sales, in the belief that they may shortly be able to sell on better terms than are at present obtainable. The general home and export quotation for Nos. 1, 2 and 3 East Coast brands is 99*s.*, and No. 1 is put at 6*d.* above that figure.

Blast Furnaces Blowing.—Only 38 blast furnaces are now in operation in this district, 10 of which are producing Cleveland pig-iron, 11 making hematite, and 17 manufacturing other kinds of iron.

Foreign Ore.—There is little or nothing doing in imported ore, and market rates remain on the basis of 23*s.* c.i.f. Tees.

Manufactured Iron and Steel.—Most of the finished iron and steel manufacturers are short of work, and are keen to book orders. Slightly better accounts, however, are given of one or two departments, and hope is entertained that orders that have been held up will be released. Among the principal market quotations are:—Common iron bars, 12*l.*; iron rivets, 14*l.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; packing (parallel), 8*l.* 10*s.*; packing (tapered), 11*l.* 10*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge and tank plates, 9*l.* 15*s.*; angles, joists and heavy sections of steel rails, each 9*l.* 10*s.*; fish plates, 12*l.* 10*s.*; black sheets, 15*l.*; and galvanised corrugated sheets, 19*l.* 5*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Although the general trade position has not improved, there is to-day a brighter and more cheerful feeling due to the better reports about the Ruhr and the prospects that that great question is nearer solution. Another affair which is of very great importance to the steel trade of the West of Scotland is the lock-out of boilermakers, and it is a hopeful sign that another attempt to end the trouble is to be made on Friday of this week, at Carlisle, when representatives of both sides will be in conference. This meeting is the outcome of discussions between the Minister of Labour, Sir Montague Barlow, and representatives of all the parties concerned which took place in London on Monday of this week. If only this trouble were ended the ship-building yards would soon open up and the steel trade would gradually get better. In the meantime there is almost nothing doing in shipyard steel, and when any improvement will take place is a matter of some uncertainty. A bright spot at the moment is light sheets, and the black sheet makers are doing a tolerably good export trade just now, but the heavier gauges, especially for the home market, are in very poor demand still. Overall there is actually no change in the steel trade position this week, and prices remain steady at last week's quotations.

Malleable Iron Trade.—Depression is still prevalent in the malleable iron trade of the West of Scotland, and the outlook continues rather dark. Fresh business is not coming in with any regularity, and consumers are only buying small lots for immediate requirements, with the result that the majority of the works are only kept going from day to day. Inquiries are not very numerous and are mainly of small tonnage. Prices are unchanged, with "Crown" bars called 12*l.* per ton delivered Glasgow.

Scottish Pig-Iron Trade.—Movement in the Scottish pig-iron trade is still within narrow limits, and even the small output at the present time is more than sufficient to meet all demands. Hematite is in poor request, while foundry grades, although the subject of a better inquiry, are not moving at all freely. Quotations are without change at 5*l.* 5*s.* per ton for Scottish hematite, delivered at the steel works, and 5*l.* 5*s.* per ton for No. 1, and 5*l.* per ton for No. 3 foundry iron on trucks at makers' yards.

Shipments of Scottish Pig-Iron.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, September 22, amounted to 864 tons. Of that total 799 tons went foreign and 65 tons went coastwise. For the corresponding week of last year the figures were 1,417 tons 8 cwt. overseas and 40 tons coastwise, making a total shipment of 1,457 tons 8 cwt.

Wages in the Scottish Iron Trade Advanced.—Messrs. James C. Bishop and Owen Coyle, joint secretaries of the Scottish Manufactured Iron Trade Conciliation and Arbitration Board, have received the following intimation from Mr. John M. MacLeod, C.A., Glasgow: "In terms of the remit, I have examined the employers' books for July and August, 1923, and I certify that the average net selling price brought out is 12*l.* 2*s.* 10·3*d.* per ton." This means that there will be an increase in the wages of the workmen of 2½ per cent. on basis rates.

THE RAILWAY BRIDGE ACROSS THE LITTLE BELT.—The projected railway bridge across the Little Belt, between the island of Fuhnew and Jutland, which for a number of years has engaged the attention of the Danish State Railways, is still under consideration and is now in fact more likely to materialise than hitherto. Borings just completed have indicated excellent conditions. In the course of two months 13 different borings have been made. This is twice as many as in 1883 when a project put forward by the Director-General of the State Railways was examined. Besides being more numerous the recent borings have also been carried to a much greater depth than before, and the examination has revealed everywhere an excellent strata of blue clay. A few more borings have to be undertaken on the shore, on both sides, in order to ascertain the bearing power of the soil over these sections. The borings have not been confined merely to those requisite in connection with the bridge planned by the State railways, but also embraced work on the site of a private project for bridging the belt.

OXYGEN-OIL EXPLOSIONS.—A study of the nature and causes of oxygen-oil explosions is being conducted by the United States Department of the Interior at the Pittsburgh experiment station of the Bureau of Mines. This problem was taken up by the bureau as a result of the oxygen explosion at the Jefferson Physical Laboratory of Harvard University, and other similar explosions, in order to supply technical information which would serve as a basis for safety precautions in the future. At the Harvard inquiry the fact was emphasised that the limiting pressures and temperatures above which compressed oxygen and lubricating oil are capable of spontaneous explosion are not known. The problem is also of importance to the Army and Navy, and to the Bureau of Mines in connection with the hazards incurred in the use of compressed and liquefied gases in the re-purification of helium. In fact, the risk of fires and explosions due to traces of lubricating oil coming into contact with high-pressure oxygen is of serious interest to all concerned with the manufacture and use of oxygen, a commodity which is now being produced and distributed on a rapidly increasing scale. A preliminary report, giving a general outline of the problem and a summary of results to date, is contained in Serial 2,507, by Mayo D. Hersey, physicist, which may be obtained from the Department of the Interior, Bureau of Mines, Washington, D.C.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The promise of an improvement in the coal trade which was suggested by the activity in chartering last week has not been maintained. A larger quantity of shipping than has been usual of late was fixed up, and it was thought that this would place collieries in a much more comfortable position. The heavy chartering certainly in individual cases considerably relieved collieries, but bad weather counteracted the more active chartering, for in many cases expected vessels have been delayed and, in consequence collieries have been compelled to seek fresh business to absorb current outputs. In the circumstances buyers able to take quick delivery have been able to secure their requirements at from 1*s.* to 2*s.* per ton below the ordinary market quotations, while prices vary considerably for similar classes of coal, being dependent on individual circumstances. Nominally, best Admiralty large is quoted at 28*s.* to 29*s.*, but supplies can be secured at 1*s.* less, while Monmouthshires rule from 26*s.* to 27*s.* 6*d.* and dry large from 27*s.* to 28*s.* Smalls of practically all descriptions continue in ample supply, with the best bunker sorts round 18*s.* and other grades from 13*s.* up, though coking smalls are steady at 22*s.* to 24*s.* Exports of coal as cargo last week according to the Custom's clearances amounted to 587,660 tons, of which 320,340 tons were despatched from Cardiff, 136,960 tons from Newport, 67,220 tons from Swansea, 49,310 tons from Port Talbot and 13,830 tons from Llanelly. Of the total shipments, France took 199,000 tons, Italy 104,720 tons, Argentina 53,200 tons, Egypt 31,400 tons, and 14,200 tons to the United States. The Danish State Railways are inviting tenders for 100,000 tons to 150,000 tons of Monmouthshire large coals for delivery over the nine months ending June next, while there are also inquiries from Portugal and Roumania for 20,000 tons each. The Swiss Federal Railways are also asking offers for 30,000 tons of patent fuel delivered up till the end of the year.

Iron and Steel.—In view of the decision to suspend import duties on goods for Japan, it is expected that there will be a good demand for galvanised sheets and certain specifications of tin-plates. In fact, inquiries are already circulating, and tin-plate prices are very firm at 23*s.* 1½*d.* to 23*s.* for boxes. Exports last week totalled only 7,944 tons compared with 13,852 tons in the previous week and 20,356 tons three weeks ago. Shipments of tin plates and terne plates amounted to 4,767 tons, compared with 5,861 tons, black plates and sheets to 365 tons against 3,776 tons, galvanised sheets to 1,858 tons against 2,092 tons, and other iron and steel goods to 954 tons against 2,123 tons.

Dredger Sunk at Cardiff.—The Cornish Salvage Company (1918), Limited, have secured the contract on a "no cure no pay" basis to raise the dredger The Duchess, which was sunk in the Roath Basin, Cardiff, a fortnight ago. The dredger, which lays in 35 ft. of water, has overturned, and her funnel and the top of the ladder is sticking in the bottom of the dock. It will be some months before she can be raised.

GERMANY'S FOREIGN TRADE.—The Commercial Secretary at Berlin (Mr. H. N. Sturrock) has forwarded to the Department of Overseas Trade an extract from the *Berliner Tageblatt*, of September 14, which states that, as a result of the continued occupation of the Customs Offices, the statistics of German foreign trade in July are again incomplete, as in the foregoing months. The following figures and comparisons must, therefore, be accepted with reserve:—

	Imports.		Exports.	
	July.	June.	July.	June.
	tons.	tons.	tons.	tons.
Total	4,159,600	4,806,600	1,054,000	889,700
Including—				
Food and drink ..	302,000	259,900	90,300	75,800
Raw materials and semi-manufactured goods ..	3,697,200	4,123,900	646,200	525,300
Finished goods ..	159,000	121,700	317,400	288,500

As before, the results of the occupation of the Ruhr are seen in the exceptionally large imports of coal and coke. For example, approximately 23,000,000 tons of pit coal—*i.e.*, more than double the monthly average of the previous year—were imported, so that the average of the seven months, January to June, 1923, is more than double the monthly average imports in 1922. In the case of coke the imports amounting to 190,000 tons have increased to nearly eight times the monthly average of 1922. The imports of iron ore have, however, declined further, namely, from 178,790 tons in June to 121,595 tons in July, less than one-seventh of the monthly average of 1922, which amounted to 917,810 tons. Some 69,793 tons of rolling-mill products and iron goods were exported in July, 59,170 tons in June, as compared with a monthly average of 193,015 tons in 1922. The exports of machinery were 27,622 tons in July, 18,247 tons in June, and a monthly average of 39,914 tons in 1922. The decline in production in the German iron and machinery industry is not less clearly illustrated by the fact that the imports of pig-iron and broken iron amounted, with 34,088 tons, to less than half the monthly average imports in 1922 (79,283 tons), while the exports amounted with 53,816 tons to more than double the average exports of 1922 (22,566 tons).

NOTICES OF MEETINGS.

THE SOCIETY OF ENGINEERS.—Monday, October 1, at 5.30 p.m., in the Rooms of the Geological Society, Burlington House, W., when a paper will be read on "Improved Method for Mass Production of Tank Glass Bottles, Jars, &c.," by Mr. Alec Ferguson, A.S.E.

THE INSTITUTE OF MARINE ENGINEERS, INCORPORATED.—Monday, October 1, at 6.30 p.m., at 85, The Minories, E. 1. Extraordinary General Meeting *re* Alterations to By-Laws.

THE INSTITUTE OF TRANSPORT.—Monday, October 1, at 5.30 p.m., in the Lecture Theatre, Institution of Electrical Engineers, Victoria Embankment, W.C. 2. Presidential Address by Sir J. G. Broodbank.

THE CERAMIC SOCIETY: REFRACTORY MATERIALS SECTION.—Thursday, October 4, at 10.30 a.m., in the Library, Grosvenor Museum, Chester. "General Sketch of the Geology of the Chester District," by Mr. T. Arthur Acton, F.S.A., F.G.S.; "Improvements in Drying Refractories or Other Goods," by Mr. J. Holland and Mr. W. J. Gardner; "The Zenith Temperature," by Mr. J. Whellor, D.Sc.; "Glass House Pots," by Mr. W. J. Rees, B.Sc. At 8 p.m., Dinner at Queen Hotel, Chester, Friday, October 5, at 11 a.m., in the Lecture Theatre, Grosvenor Museum, Chester. "Notes on the Proctor Dryer," by Mr. A. H. Middleton; "New Methods of Producing Gas for Industrial Operations," by Mr. R. Maclaurin; "The Effect of Salty Coal upon Refractory Materials," by Mr. L. M. Wilson, M.Sc.; "Carbonisation of Clay," by Mr. Walter Smith.

THE DIESEL ENGINE USERS ASSOCIATION.—Friday, October 5, at the Institution of Electrical Engineers, Savoy-place, Victoria Embankment, W.C. 2. Discussion on "Some Notes on a Broken Crankshaft and the Manner in which an Emergency Repair was carried out on a Diesel Engine in Barbados," and, if time permits, "Some Particulars of the Comparative Running Costs of Steam and Diesel Driven Pumping Plants in Alexandria, Egypt."

THE WEST YORKSHIRE METALLURGICAL SOCIETY.—Saturday, October 6, at 7 p.m., at the George Hotel, Huddersfield. Annual General Meeting.

THE INSTITUTE OF COST AND WORKS ACCOUNTANTS.—The headquarters of this Institute have been moved to 6, Duke-street, St. James', London, S.W. 1.

PROPOSED MERSEY TUNNEL.—With a view to improving communication between Liverpool and Birkenhead, the proposal has been put forward to construct a tunnel under the Mersey. The subject has been considered by experts, and at a meeting of the Merseyside Co-ordination Committee held on Wednesday last, Sir Archibald Salvidge explained that a bridge was out of the question for financial reasons, and that a 44 ft. tunnel could, according to estimates, be constructed for about 4,000,000*l.* less. The tunnel would have two branch outlets on each side of the river. As the tunnel would have a national value from the highway point of view the Government is to be approached with regard to a grant for the scheme, which it is pointed out would also provide useful work for the unemployed.

CARBON TETRACHLORIDE FIRE EXTINGUISHERS.—Tests made by the United States Department of the Interior at the Pittsburgh experiment station of the Bureau of Mines relative to the hazards to fire fighters from gases and smoke resulting from the application of carbon tetrachloride extinguisher to electric arcs, burning insulation, or fires such as may occur in electrical apparatus and machinery, are summarised in a serial just issued by the Department. It was found that the application of 1 cub. ft. of carbon tetrachloride fire extinguisher to electric arcs and burning insulation in a chamber of 1,000 cub. ft. capacity, developed phosgene, chlorine and hydrogen chloride in quite dangerous concentrations. Carbon tetrachloride vapours, sulphur dioxide and carbon monoxide were also formed in less dangerous concentrations. Rats exposed for 15-minute periods to the gases evolved from the use of carbon tetrachloride on the arcs died or were seriously affected. These tests confirm conclusions drawn from previous tests by the Bureau of Mines that it is dangerous to breathe the gases that may be generated from 1 quart of carbon tetrachloride extinguisher applied to a fire in a confined space from which escape is difficult or impossible, and from which the gases would not be removed by ventilation. So far as is known, carbon tetrachloride extinguishers are the most effective and satisfactory of any that can be applied to electrical fires with safety from shock to the operator. Arcs of 60 amperes direct current and 220 volts, and 35 amperes and 500 volts, were easily extinguished with a 1-quart carbon tetrachloride fire extinguisher. The purpose of these experiments of the Bureau of Mines was to determine the extent of the danger from poisonous gases arising from use of carbon tetrachloride extinguisher on electrical fires, and to promote safety of fire-fighters through their knowledge of those conditions. It is not the purpose to discourage the use of carbon tetrachloride extinguishers, which are safe under all conditions, excepting those of close confinement of fire gases in absence of ventilation, and lack of ready escape for the operator from the gases. Such conditions may occur in unventilated parts of mines, vaults and cellars. They do not usually exist in buildings or the entries of mines where electric locomotives are used for hauling, since these customarily are well ventilated.

REINFORCED CONCRETE BRIDGE ACROSS THE RIVER THAMES AT READING.

CONSTRUCTED TO THE DESIGNS OF MESSRS. L. G. MOUCHEL AND PARTNERS, LIMITED, ENGINEERS, WESTMINSTER.

(*For Description, see Page* 385.)

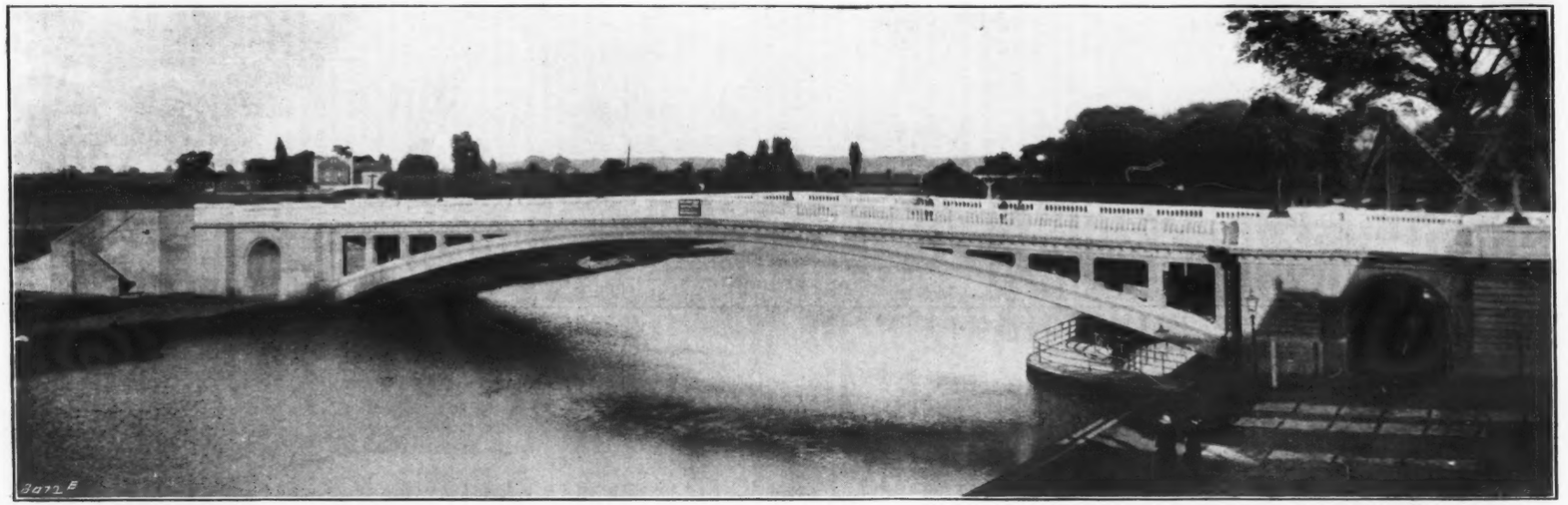


FIG. 21. GENERAL VIEW OF COMPLETED BRIDGE.

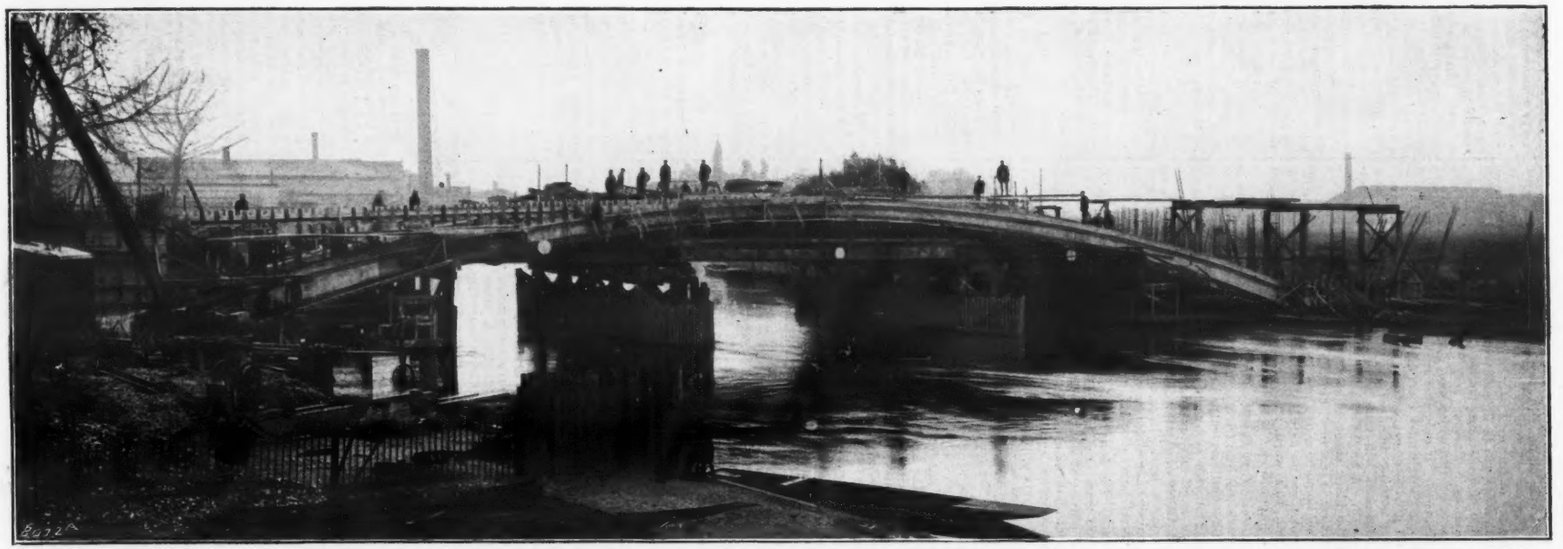


FIG. 22. VIEW OF MAIN SPAN DURING CONSTRUCTION, SHOWING SUPPORT OF SHUTTERING.

ENGINEERING.

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ENGINEERING.

FRIDAY, SEPTEMBER 28, 1923.

INTANGIBLE EXPORTS.

MATERIALISM, though long since discredited as a system of philosophy seems still to be regarded by many as an adequate foundation for economic theories. The recognition of the futility of materialism as a philosophy arose largely from the realisation that history presented us with a world of free agents, where the course of events was not decided by mathematical equations, but was characterised by a certain spontaneity, such that had Cleopatra's nose been a trifle askew, future happenings might have been materially modified. Similarly, it was a disregard of historical teachings which led many of our economic materialists to reiterated assertions that great wars were no longer possible because the leading nations could not afford to quarrel with their best customers. This particular economic fallacy is naturally discredited for the moment, but recent utterances have shown that materialistic views of economics are still widely prevalent. Its principal protagonists are the financiers on the one hand and the Labour Party on the other. For the latter there is some excuse, since many of its members, like Molière's hero, who had spoken prose all his life without knowing it, are materialists without realising the fact. No such plea in extenuation can however be admitted in regard to those who have recently been arguing, with a volubility which recalls old-time Parliamentary oratory, that from the standpoint of economics, it is a matter of indifference whether or no loans overseas are, or are not, accompanied by conditions tending to promote the development of our manufacturing industries. Whether such restrictions be politic or not, involves, of course, more than questions of pure economics, but we are concerned here solely with the fallacy of certain arguments advanced against such proposals.

Reduced to its simplest term, the thesis maintained is that since loans for overseas are exported in the form of goods and not of cash, it is a matter of indifference to us in what class of goods this export shall be made. No doubt so far as the immediate interests of the banker and commission agent are concerned, it is a matter of indifference whether the goods by the export of which a foreign credit is established take the form of, say, china or of china clay. To paraphase Tennyson, however, "We are not money mongers all," and the form the export takes is of vital concern to the other classes of the community. Moreover, even the basic proposition is not a fundamental truth but merely an approximation thereto. Certain foreign credits are, as a matter of fact, established without the export of anything material from this country. Authors, for example, receive royalties on books published abroad, and if we follow matters out, it will be easily evident that credits established abroad by the export of highly finished goods include payments for the exercise of intellectual faculties just as surely as do an author's royalties.

Mind is, in short, the main factor in the creation of wealth, and it is accordingly not a matter of indifference to the community whether foreign credits are established by the export of minerals, the winning of which affords relatively but little scope for the exercise of much besides muscle, or whether as in the case of an export of beautiful porcelain the major part of the value is due to certain intellectual faculties. This was very clearly realised by some of our competitors before the war. Practically the whole of the tungsten used for special steels and electric lamps was mined within the Empire, and at the outset part of it was refined here. The industry was naturally an infant one and hence had not behind it any great amount of capital, nor were the numbers employed large enough to make its destruction a matter of immediate national concern. The astute business men who ran the foreign refineries saw therefore their way clear to establishing a monopoly by undercutting prices until our own refineries were closed down, and this accomplished, they would then only furnish the metal at their own price to our consumers, and under conditions strictly controlling the uses to which it was put. The rough work of mining the ore was left to us, but our own metallurgists and chemists were deprived of a career affording opportunities for the creation of new wealth by the exercise of their talents.

In view of the predominant part played by mind in the creation of wealth, there was a certain naiveté in the views expressed by our economists of the great Exhibition era, in assuming that other nations would be content to leave Great Britain as the workshop of the world, free to reap unchallenged all the vast wealth represented by the intangible or non-material factor in her exports.

Unfortunately some of our rivals have appreciated more fully than ourselves the true source of wealth from manufactures. A notorious example is provided by the dye industry, which, originating here, was developed with greater intelligence abroad although we had the more competent chemists. In commercial and financial circles, however, the view has been prevalent that business ability is all that is required for the conduct of a highly technical trade. The smart business men who, many years ago, took over the prosperous chemical establishments of Simpson, Maule and Nicholson, which had been built up by a directorate that included an able chemist, thought themselves competent to decide questions of policy in opposition to the advice of the extremely able chemists included on their staff. The result was the reverse of satisfactory, and the recent resignation of a technical member from the staff of an important industrial firm, because he was allowed no share in shaping policy, raises fears as to whether history may not repeat itself, and that a business which in the interests of national security has received governmental aid may prove unable to contend with establishments where more enlightened views are held as to the value of the technical expert.

In this connection it is very curious to note how certain national traits persist. Whilst often loth to be guided by competent expert opinion, the British financier sometimes falls a ready prey to the charlatan or plausible second-rater. The classical case is afforded by the first Atlantic cable which the board entrusted to one who was essentially an amateur electrician in place of to W. Thomson, afterwards Lord Kelvin, who had already acquired an

international reputation as a savant of exceptional ability. The amateur decided that the solution of the problem of rapid signalling was to use very high voltages, with which he promptly destroyed the insulation of the cable. Quite recently, again, in direct opposition to the advice of his experts, the head of one of our electrical firms acquired the British rights for a worthless steam turbine of Continental origin. This, however, is only another variant of an old story. Patent rights of this kind have been bought wholesale by the business heads of British Engineering firms without, in most cases, the slightest attempt to secure the advice of independent experts. Perhaps, they feared that these might repeat the advice given some years back by Sir Charles Parsons who said that to maintain a leading position a firm should expend in experimental work from 1 to 3 per cent. of its annual turnover. Of this, in the very nature of things, a large proportion will lead to nothing of value, and it is this inevitable fact of the situation which apparently leads so many of our business men to prefer to buy what they are told is a completely developed invention rather than to face the writing off yearly of uncertain sums expended in unsuccessful experiments.

We have, however, enormous financial burdens to liquidate, and we shall not succeed in doing this unless we can increase our non-tangible exports by the establishment of new manufactures and the improvement of old. Little is to be gained by this favourite device of importing ready-made ideas, because in the very nature of things, our competitors who originated them, will necessarily know more about them than we who receive them at second hand, and who too often employ so ill-educated a technical staff that we have to import not merely the idea but also the men to show us how to carry it out.

If, on the other hand, we do our own thinking, we retain an advantage even over those who may take foreign licences from us. The 20,000–25,000 kw. steam turbine, for example, which Messrs. Parsons supplied to Chicago in 1912, established a new record, and relatively speaking has not yet been surpassed, although from the absolute standpoint better steam rates have since been obtained. These have, however, been achieved either with turbines having a larger "K" or operating with steam at a higher pressure or higher superheat. This is the type of export which we must aim at increasing. It is essential that we shall be paid for the "know how" rather than for mere material and labour, although the bankers' profit on such transactions may be as high with the latter type of export as with the former.

In this connection a disquieting feature is the low standard demanded by some universities for the B.Sc. in engineering. We are often offered for publication articles by men entitled to this distinction which show a most imperfect acquaintanceship with fundamental principles of mechanics and thermodynamics, and this low standard is reflected in the average text-books prepared for the use of aspirants to this degree. New ones are being constantly received for review, but for the most part there appears no obvious reason for their production. The author has commonly nothing new or striking to say, and his text-book recalls the remark of one of the characters in the celebrated "Jumping Frog," who, as he left, observed, "I don't see no points about that 'ere frog what is any different from any other kind of frog," and it is really difficult to find any distinguishing characteristic in most of the new books offered to our students. What they do is to afford practice in answering the kind of question which is in favour with the average examiner, and these seldom call for much thought on the part of the candidate, but merely for a familiarity with formulas.

This condition of affairs is reflected in the number of good technical appointments which are being secured by graduates from foreign technical schools, and it is time for our own to set their house in order. Part of the present condition has no doubt arisen from a desire to make our technical courses such that the average man can follow them. The complaint was made that only exceptional individuals could follow the lectures of an Osborne Reynolds, and there was a consequent reluctance to appoint men of his calibre to engineering chairs. One result of this policy has been, we fear, the lowering of standards to which we have above referred. It is possible that the usual three-year course is too short for the average youth, and that an additional year should be required from all but those who show special ability. Possibly it would be well also to have special research chairs, the occupants of which would lecture only to advanced students, but would be afforded time for research of a fundamental character, as distinct from the mere repetition of the measurement of stresses, pressures, temperatures, &c., commonly dignified by the name of research. There are thousands of men who can conduct successfully "researches" of this character, for one who could found the theory of lubrication, which it should be noted was based wholly on experiments made by somebody else, and which Osborne Reynolds made no attempt to repeat. It is research work of the Reynolds type that it is expedient to foster, and not mere experimental ability or manipulative skill valuable as such qualities may be in their place.

SCIENTIFIC EXHIBITION AT LIVERPOOL.

THE very extensive programme arranged for the entertainment of the visitors to Liverpool in connection with the recently-concluded meeting of the British Association, included an exhibition of scientific instruments and apparatus which was held in the Central Technical School conveniently situated near the reception room in St. George's Hall. In addition to the collection of apparatus shown, among which most of the leading British manufacturers were represented, demonstrations were given at frequent intervals of Professor A. O. Rankine's apparatus for the transmission of speech by means of a modulated beam of light and of Dr. E. E. Fournier d'Albe's optophone, as developed by Messrs. Barr and Stroud, Limited, of Glasgow, for enabling the blind to read ordinary printed matter. Both these instruments have been described in our columns so that our readers will be familiar with the principles employed. The Meteorological Office of the Air Ministry had an exhibit including a miniature, but self-contained, forecast-service, which provided information as to forthcoming weather conditions which was of considerable interest to the visitors.

The exhibits of a purely engineering character were not particularly numerous and most of them are well known to engineers. In this category we may include the coal meter and "V" notch water meter shown by the Lea Recorder Company, Limited, 28, Deansgate, Manchester; the differential draught gauge and CO_2 indicator at the stand of Messrs. W. R. Patents, Limited, Leeds; the draught gauges, gas-analysis apparatus and combined CO_2 and draught recorder exhibited by Messrs. Duguids, Limited, of Lymm, near Warrington; and the feed-water regulator and "V" notch flow recorders shown by Messrs. J. Gordon and Co., Limited, of Windsor House, Kingsway, W.C.2. The last-mentioned firm, however, showed an instrument of recent introduction known as the "Duplex-Mono" fuel combustion recorder which gives a continuous record on a chart, not only of the percentage of CO_2 in the flue gas but also of the CO and other unburnt gases. The record consists of a series of parallel lines, the alternate lines referring to CO_2 and unburnt gases, respectively, and the length of the lines giving the percentage of each.

The Paterson Engineering Company, Limited, Windsor House, Kingsway, London, showed an apparatus, known as the "Chloronome," for the sterilisation of water by means of chlorine gas. The chlorine is stored in liquid form in steel cylinders and the apparatus provides for the reduction of the pressure of the gas as well as for measuring it and distributing it throughout the water to be treated. The particular apparatus shown was suitable for supplying up to 10 lb. of chlorine a day, which would be sufficient for the treatment of from 1,000,000 to 2,000,000 gallons of water. The apparatus has been installed for the treatment of condenser cooling water for inhibiting the fouling of the tubes, for the purification of the water in swimming baths and for the sterilisation of sewage, as well as for the purification of drinking water.

Of the electrical exhibits we may mention that of Messrs. British Insulated and Helsby Cables, Limited, Prescot, which included one of the firm's butt-welding machines in operation. One of the recent applications of these machines is in connection with the manufacture of valves for internal-combustion engines, the stem of the valve being made from drawn bar which is butt-welded on to a drop forging which forms the valve disc. A recent development in connection with seam welding which is performed by moving the work intermittently between two rollers, is the introduction of a choking coil in the electrical circuit arranged so as to cut down the current automatically while the work is moving and to increase it while the work is stationary, the object being to prevent the burning of the parts which are not in actual contact while the current is passing.

The same firm showed a number of large condensers for improving the power factor of alternating current systems. The units from which these condensers are built up are composed of strips of tinfoil rolled up with tissue paper so as to form a cylinder which would be solid but for the fact that sheets of corrugated paper are included in the roll for cooling purposes. The units necessary to give the required capacity are mounted on vertical rods and immersed in tanks containing insulating oil. One of the condensers exhibited was rated at 102 k.v.a. at 600 volts and 50 cycles, its capacity being 900 microfarads. We understand that the firm have already supplied condensers totalling upwards of 40,000 k.v.a.

An interesting exhibit shown by Messrs. H. W. Sullivan, Limited, Winchester House, E.C.2, was Mr. K. C. Cox's selenium magnifier for submarine telegraphy. In this instrument, the image of a grid is projected on to the mirror of a receiving galvanometer connected in the submarine cable circuit, and reflected by the mirror on to a selenium cell of special design. The cell is subdivided into parallel strips corresponding to the image of the grid and the subdivisions are connected so as to form the four arms of a Wheatstone bridge. The image of the grid is adjusted so that, when the galvanometer mirror is in the undeflected position, each of the four selenium cells forming the arms of the bridge is half illuminated and half dark, and the bridge is balanced in this condition. A very minute movement of the galvanometer mirror will then vary the amount of light falling on the selenium cells increasing the light on two of the cells and diminishing that on the other two. This causes a considerable alteration in the resistance of the cells, disturbs the balance of the bridge and so allows a current to flow in the local receiving apparatus. The current magnification obtainable is up to 10,000 times (or in special cases up to 20,000 times) the strength of the received signal, whereas the magnification required in practice is from 200 to 1,000 times. The effect of selenium "inertia" is eliminated by shunts placed across the local apparatus as commonly employed in telegraphy. We may add that selenium cells similar to those used in the magnifier are made by Messrs. Sullivan in various sizes for other purposes.

Several firms exhibited laboratory apparatus for use in schools and technical colleges, but the stand of most interest to engineers was that of Messrs. G. Cussons, Limited, Broughton, Manchester. In addition to their well-known ribbon-recording Atwood's machine, the firm showed models for demonstrating the whirling of shafts, the effects of acceleration and mass, and of centrifugal force. Mention should also be made of apparatus due to Professor G. E. Beggs, of Princetown University, New Jersey, for determining the stresses in roof trusses, arched bridges and statically-indeterminate structures generally, by means of celluloid models which Messrs. Cussons now manufacture. The principles of the apparatus were described by Professor Beggs in a paper read before the American Concrete Institute during the 1921–22 session.

Electrical and other measuring instruments, pyrometers, wireless apparatus, microscopes and accessories, chemicals and drugs, chemical balances, X-ray apparatus, &c., were shown by numerous well-known manufacturers, but the demands upon our space prevent us from referring to these in detail. We may mention, however, a new form of X-ray spectrograph made to the design of Dr. A. Müller

and exhibited by Messrs. Adam Hilger, Limited, 75A, Camden-road, N.W.1. It is used for the analysis by crystal structure of crystals and powders, and is of compact construction and particularly simple and convenient to operate. Another interesting instrument shown by the Empson Electrical Engineering Company, Limited, 39, Victoria-street, S.W.1, is known as the "Dielectrimeter" and has been designed to provide a portable, simple and convenient apparatus for determining the dielectric strength of insulating oils used in transformers, oil switches, &c. It comprises an induction coil of special design which supplies high-tension current to an adjustable spark gap having spherical electrodes. This spark gap is connected in parallel with a fixed gap formed of two ½-in. balls contained in a glass cell in which the oil to be tested is placed. The electrodes of the external gap are then gradually separated by screw mechanism until a spark passes between the electrodes immersed in the oil, the voltage at which this occurs being read by means of a pointer moving over a calibrated scale reading up to 31,000 volts. A gauge is supplied with the apparatus to set the electrodes of the fixed gap at a distance of 0·15 in. apart as required by the British Standard Specification for insulating oils.

Other notable exhibits were the "Frenophone" friction-operated loud-speaking telephone, the principles of which were explained on page 661 of our last volume. This was shown in operation by Messrs. S. G. Brown, Limited, Victoria-road, North Acton, W.3, but the principal exhibit of this firm was the Brown gyro-compass. A special feature of this apparatus is the employment on the steering repeater of an automatically magnifying dial, which enables a course to be steered with great ease and accuracy, and is claimed to result in an appreciable economy in fuel consumption. The Sperry Gyroscope Company, Limited, 15, Victoria-street, S.W.1, also had a stand at which their well-known gyro-compass and automatic course recorder were displayed. Finally, we may mention an instructive collection of microphotographs and thin transparent sections of coal shown by the Microscopic Research Department of the Lancashire and Cheshire Coal Research Association, and the exhibits of Messrs. T. Firth and Sons, Limited, and Messrs. Hadfields, Limited, both of Sheffield, showing the latest developments in research work on steel. The exhibition, which opened on the 10th instant, was closed on Saturday last, the 22nd instant.

THE COAL, ELECTRICAL MACHINERY AND STEEL MARKETS OF CANADA.

SIR AUGUSTUS M. NANTON, speaking at Toronto early this year, gave expression to a prevailing sentiment in Canada when he said "It is the duty of all of us, if for no other reason than self-interest, to strengthen our ties with, and try to do more business with, the Old Country than we have done in the past. We cannot be successful unless we export, and Great Britain cannot buy from us unless we buy from her." With such a strong desire as does exist to link up the component parts of the Empire by increased trading there must be very great difficulties in the way of its achievement if it is not successfully accomplished. In a report to the Department of Overseas Trade on the "Financial, Industrial and Commercial Conditions in Canada to June, 1923," which was recently published, Mr. F. W. Field, H.M. Trade Commissioner in Toronto, gives an indication of some of the obstacles. The competition of Canadian and United States manufacturers in certain lines has become so keen that the sale of British goods is only effected with great difficulty. There are, however, some trades in which the position is much better and a substantial share of the business has been secured. In these cases a careful study has been made of the market and its conditions, and steps have been taken to meet them. It must still be said, and with great regret, that some British firms do not appear to have bothered much about the actual conditions to be met in this market or have tried to conduct business by unsatisfactory local representation, and have consequently suffered disappointments, sometimes leading to the abandonment of even these small efforts. The necessity for personal visits of traders and manufacturers to Canada is emphasised by Mr. Field, who gives it as his considered opinion and that of established agents, and branch managers of British concerns, that reports can only be useful as a general guidance or as providing supplementary information to that acquired locally.

The magnitude of the production of cereals is the index to all Canadian activity. The harvest of last year was a particularly good one and the wheat crop was, in fact the largest ever known, but as the produce was marketed at low prices the agricultural people were only able to liquidate a part of the debts contracted during the last two poor seasons. This has had an important influence upon the industrial and commercial situation during the year, and the number of failures has constituted a record. These were due to the inflation and over-extension which followed the Armistice, and it is ample testimony to the recuperative powers of Canada and the energy of her people that there have been very few serious commercial reverses. While many industries such as textiles, pulp, paper and motor vehicles were quite active during the year, the metal, machinery and general engineering trades were quiet.

For the first time for many years quantities of coal were imported from Great Britain, and in all about 817,000 tons were shipped. This was due to labour troubles in the United States from which large quantities of fuel are normally obtained. There is at present in America an agitation against the exportation of anthracite which it is believed will ultimately result in a complete embargo, and consequently Canada is forced to find a substitute for that fuel. Since the stoves fitted in Canadian homes are mostly constructed for the combustion of anthracite, the reduction of bituminous coal to coke seems to be indicated as a necessity. It is possible, however, that the establishment of a permanent trade in Welsh anthracite, and possibly other coals, might be resorted to, and it would give the British exporters a very valuable market. Efforts in this direction were being made early this year by the Welsh exporters in co-operation with Canadian firms. In such a scheme the water-borne coal will need to be unloaded at Montreal and reloaded into vessels carrying not more than 2,200 short tons. A further transfer to trucks at the Ontario lake ports will be necessary, and at present there are no proper facilities available for that purpose.

Continued progress is reported in the development of water power resources, and in 1922 the total installation in Canada amounted to 3,000,000 h.p., of which 240,000 h.p. was made available during the year. Projects now under construction or actively in preparation have a total capacity of nearly 1,000,000 h.p., while other suggestions are under consideration. With this expansion there has been an accompanying rapid growth of household consumption of electricity, which may be gauged from the fact that in 17 of the largest cities and towns of Ontario there is an average of one electric range for every six electricity consumers. In 20 of the Canadian municipalities there are over 18,500 electric cooking ranges in use. Cheap rates of supply are obtainable, which for cooking amount to only 0·9 cent per unit in most of the large municipalities, while the highest rate, that of a small concern, is only twice that figure. The Hydro-Electric Power Commission is extending cables wherever economically possible, and in the last year approximately 355 miles of rural line were constructed. The demand for all kinds of electrical equipment, large and small, is therefore very good, and the Canadian and American houses had a time of good business in 1922. The increased consumption in many districts is such as to make necessary the duplication of mains and feeders, and orders for line material, transformers and other equipment will be placed shortly. There is keen competition to face, but home firms have shown what can be done in the tenders submitted for the supply of turbo-generators to the City of Winnipeg, when three British firms made offers which compared favourably with those of the American competitors.

The steel industry in Canada follows that of the United States as far as the primary products of pig-iron and ingot steel are concerned, the Canadian production of these materials having shown no great advance for many years. There has been, however, great development in the production of finished steel, and this is expected to continue. As the steel industry is dependent on the fortunes of the coal and steel industries of the United States, the Canadian manufacturers are concerned about the maintenance of their supplies of raw materials, and it is possible that developments in the production of the primary materials in Canada will result. The Ontario Government has appointed a committee to investigate the possible utilisation of the iron ore deposits in the province, and research work is being conducted on the treatment of pyrrhotite ores for the production of electrolytic iron, as Canada has large quantities of available minerals of that type.

Traders should make themselves familiar with the work of the Canadian Engineering Standards Association, the published specifications of which must be valuable to those who look for an extension of their business in this market. Already steel bridges, transformers for distribution schemes, galvanised telegraph and telephone wire and wire ropes have been dealt with, and other reports are anticipated shortly on incandescent lamps, watt-hour meters, poles for transmission lines, reinforcing material for concrete and commercial bar steel.

THE IRON AND STEEL INSTITUTE.

(*Concluded from page* 373.)

THE members re-assembled in the Milan Chamber of Commerce on the morning of Tuesday, the 18th inst., to conclude the reading and discussion of papers.

A telegram was read from Sir Robert Hadfield expressing his regret at being unable to be present at the meeting, and adding that he was sure the Institute would receive in Milan the best welcome. A telegram in reply was sent to Sir Robert by the chairman.

A reception of the members by the Syndic of Milan (Senator L. Mangiagalli), and the Municipality of Milan, was held on Tuesday mid-day, at the Town Hall, when a wreath was deposited by the president, Mr. F. Samuelson, against the tablet at the Town Hall, commemorating the death of those inhabitants of the city who fell in the war. On the preceding evening, a reception was held at the Chamber of Commerce.

STEEL CORROSION.

The first paper taken at the meeting on Tuesday morning, the 18th inst., was contributed by Dr. W. H. Hatfield, and dealt with "The Influence of Nickel and Chromium upon the Solubility of Steel (in Relation to Corrosion)." Dr. Hatfield read it in abstract, and we reproduce it—also in abstract—on page 415.

The author referred to the discovery by Brearley in 1913 of a 12 per cent. to 14 per cent. chromium stainless steel, and to the work of German metallurgists on the quarternary rust-resisting steels containing both chromium and nickel. The paper dealt with the author's experiments in regard to the corroding effect of nitric, sulphuric and hydrochloric acids on a number of different steel alloys. With regard to his observations to the effect that the special steels, particularly the high chromium and nickel steels deserved more attention, it was interesting to record, added Dr. Hatfield, that a remarkable class of corrosion and acid-resisting steels had, as a result of these researches, been developed, and were now available for the industrial world. The characteristics of these new steels were very interesting as besides being particularly resistant to corroding influences, they had excellent mechanical properties, bearing, for example, up to 60 tons to 70 tons maximum stress in tension, accompanied by an elongation of 25 per cent. to 35 per cent. They were also non-magnetic. This latter feature was, of course, of very great importance, when considering certain items in electric machinery and in other directions, where such mechanical properties were particularly desirable. The name "Wind water" which had been applied to these steels was a particularly appropriate one, in that their resistance to corroding effects was so considerable that even when placed upon the wind and water line under marine conditions this resistance was satisfactory.

Professor Giolitti emphasised the importance of corrosion from the practical point of view. He

(the speaker) called attention to the peculiar results obtained when gradually increasing the chromium content. It would be interesting in this connection, he thought, to give the theoretical results and the structure of the steels in question.

Sir William H. Ellis said Professor Giolitti had referred to the scientific aspect of the problem. He (Sir William) would refer to it from the point of view of the engineer. In civil engineering structures corrosion was a great source of trouble. The painting cost was enormous. Metallurgists were doing excellent work in endeavouring to introduce steels less liable to being attacked. The researches by Dr. Hatfield were most useful in this line. He (the speaker) would however, like to point out that scientists and metallurgists were very prone to introduce figures, for mechanical tests among others, which figures were reproduced in technical journals and in specifications, and could not be reproduced in everyday practice. He would ask the author not to put a too tempting bait forward. Figures obtained in laboratory practice could frequently not be obtained in the usual steel works practice without considerable expense.

Mr. J. A. Matthews said the expense of manufacturing such steels might be great, but they had been made in the United States for many years past. They gave to them in the United States the traditional name "Resista," and these steels were used for a number of purposes where there were corrosion risks, such as in coal mine machinery, for example. They had a wonderful range of properties.

Dr. E. L. Dupuy stated that he had observed in high nickel steels a selective corrosion at the boundary of the crystals, resulting in the separation of grains, a phenomenon which did not occur when chromium was added. He thought that the action of chromium was to insure the homogeneity of the metal as well as to stabilise the austenite at low temperatures! A corrosive mixture of very great importance in chemical industry was the low-concentration sulphuric acid—nitric acid solution in water. He would very much like to know whether Dr. Hatfield had had occasion to carry out experiments with this, and whether he had found differences in the behaviour of different steels under such a corrosive action.

Mr. C. H. Ridsdale greatly appreciated the paper, and referred briefly to the properties of a steel containing 60 per cent. of nickel and 12 per cent. to 14 per cent. of chromium.

In the course of his reply, Dr. Hatfield said he was glad Professor Giolitti had emphasised the peculiar results obtained when gradually increasing the chromium content. It was a fact that whilst when one arrived at 12 per cent. to 14 per cent. of chromium and experimented with nitric acid one got complete resistance, yet there were the intermediate percentages, down to 5 per cent., where the solubility was intensified, which indicated the complexity of the problem. In replying to Sir William H. Ellis he said that the chromium in the earth crust was about 0·35 per cent., whereas iron had quite a number of units, and as much as metallurgists would like to inform civil engineers when all steel could be made rustless, he was afraid the limitation set by nature precluded the regular addition of from 12 per cent. to 14 per cent. of chromium. The resources at disposal indicated that there were available very indifferent possibilities for achieving the object Sir William had indicated. In America copper had been added to steel with a view to increase its resistance to corrosion; this meant using a large amount of copper, and on the other hand experience had shown that the results obtained thereby were not so good as had been anticipated. The best engineers could do was to use good steel, *i.e.*, pure steel. High phosphorus and high sulphur contents augmented the corrosion effects. Many influences came into play, but the purest steel had the greatest resistance to corrosion. It was quite clear that he (the speaker) did not deal with the million tons of steel for structural purposes, but with the 10,000 tons and the 1,000 tons for special uses, and in this latter field the problem was solved. In regard to his figures of tests, there were not merely "laboratory figures," but actual ones. In reply to Mr. Matthews, he was aware that a large amount of work had been done in the United States in the same field and with good results; the work in America in rustless steel had developed in parallel lines with that on this side. Dr. Dupuy had put forward a very interesting scientific point in mentioning the corrosion of the crystal boundary in a high nickel steel, and the absence of this when chromium was added. He (Dr. Hatfield) could confirm that point from experience, and referred to the illustration in his paper of a 36 per cent. nickel steel ingot (with manganese), showing the result of forging. If the ingot were poured hot there were found acicular crystals; when hammering, every one separated from each other. In regard to the nitric and sulphuric acid solution referred to by Dr. Dupuy, he (the speaker) regretted that his experience was a similar one; he had not yet produced a steel which would resist that combination. In reply to Mr. Ridsdale, the metal referred to, a low carbon, nickel-chromium alloy, having 60 per cent. nickel and 12 per cent. to 14 per cent. chromium could hardly be called a steel.

The Iron Mines of Nurra (Sardinia).

The second paper contributed to the meeting on Tuesday morning, the 18th inst., dealt with "The Iron Mines of Nurra (Sardinia)," by Engineer Cesare Martelli and Dr. Tito Sotgia. It was read in abstract.

The district of Nurra is situated at the extreme north-west of the Island of Sardinia; it is bounded on the east, on the land side, by a line passing through Porto Torres, Olmedo and Alghero. The paper gave in detail the geological formation of the district. On account of the regularity of their composition and their excellent physical condition, the Nurra iron ores, the authors stated, would be as greatly sought after as those of Normandy; their analysis is almost identical to that of the Normandy ores. The surveys already made indicate the probable existence of over 10,000,000 tons, chiefly carbonate. Preparatory work was commenced at the site in 1915. Shafts, calcining kilns and a railway to Porto Torres have been built and the work is being extended.

Nickel-Chromium Steels.

The third paper taken at the meeting on Tuesday morning, the 18th inst., dealt with "The Changes in Some Nickel-Chromium Steels," contributed by Mr. W. T. Griffiths, of the Research Department, Woolwich. It was read in abstract by the secretary.

The paper described a series of researches with the steels in question, and a modified form of the Andrew dilatometer used by the author. It emphasised the importance of getting these steels as homogeneous as possible before hardening them, and the great care to be taken in the production of the original ingot. It called attention to the benefit to be derived by getting all carbides into solution and the elements uniformly distributed in the iron before quenching, also to the advantage of a preliminary quenching treatment before the hardening treatment. A point made by the author was the advisability of altering the composition to suit the size of the article quenched. All things being equal, it would appear preferable to increase the nickel content rather than the chromium, as the latter needed a higher temperature of heating to exert its maximum effect. The paper brought out the importance of quenching at a sufficiently rapid rate through the lower point as well as through the higher temperatures. There also seemed a possibility, especially in the case of smaller articles, of employing a moderately slow rate of cooling through the ordinary Ar1 position and of quenching from lower temperatures, thus avoiding distortion and the possibility of cracking.

Dr. E. L. Dupuy said the communication of Mr. Griffiths was important in that it called attention to the necessity of insuring the homogeneity of the nickel chromium steels by forging and by preliminary treatment previous to the final treatment. He (the speaker), however, differed from him in one of his conclusions (that having reference to the benefit to be derived by getting all carbides into solution and the elements uniformly distributed in the iron before quenching). He (the speaker) had occasion to study with the Chevenard dilatometer the heating and cooling curves of a certain number of nickel chromium steels, and also the mechanical properties of specimens having undergone the same treatment. As has been reported by Portevin, Garvin, Chevenard and Griffiths, the heating at a high temperature above the critical point modifies the way in which steel behaves on cooling. The dilatation curves enable the phenomenon to be followed exactly. In fact, the metal in the austenitic region, instead of dilating in a regular manner, gives a curve having a heavy concavity; this points to a progressive trans formation. When heating has been at a relatively high temperature there is a great variation in length on cooling, the points Ar1 and Ar2 being at a temperature below 400 deg., that is to say, in the region where the metal has the maximum of fragility. This fact, combined with the evidence of a large crystal structure, inevitably leads to cracks in the metal. The danger of a treatment at a high temperature tends to balance, and more than balance, the gain due to homogeneisation, if every precaution is not taken to render undetrimental the passing through the lowered points.

The other papers on the list were taken as read, and all the authors received the thanks of the meeting for their contributions.

The votes of thanks to the members of the Reception and Executive Committees, and to the Chamber of Commerce, concluded the proceedings.

Visits.

Visits to numerous works and places of interest in Italy are to take place down to October 3. The works include the Lombardy Iron and Steel Works, those of the Breda Company, of the Ilva Company, the Magona d'Italia, the Italian Metallurgical Society, the works and shipyards of the Ansaldo Company, and the establishments belonging to the Fiat Company. Particulars of all of these will be published in the Proceedings of the Institute.

NOTE.

Large Submarines.

In the programme of building submitted by the French naval authorities the construction is proposed for the period 1924–33 of four submarines of the cruiser type of 2,400 tons and 30 of 1,100 tons surface displacement. The smaller units are to have a maximum surface speed of 16 knots and a radius of 4,300 miles, while at a speed of 10 knots they will be able to cover a distance of 11,000 miles. They are to be provided with 10 torpedoes of 21½-in. diameter tubes and will carry six in reserve, while a gun of 4-in. calibre will be part of the armament. We note from *Le Moniteur de la Flotte*, of September 22, that there has been much discussion of late between the French naval specialists on the question of the necessity for any increase in dimensions beyond those of the smaller type. One school of thought contends that the limit has been reached, and that the smaller boats are quite sufficient to meet the principal needs of the Navy and are all that is warranted by the financial resources of the country. Others contend that the cruiser type has the great advantage of being able to carry 24 torpedoes, and travel at 19 knots on the surface with the same radius of action as the smaller vessel. In certain cases it is stated that the larger vessel will be of more use than two units of the smaller size, costing the same total sum. Of large vessels in commission, or under construction, France has the Halbronn (Ex. U-139), of 2,000 tons, and the United States has on the stocks submarines of that size, while Britain has the "M" class of 1,600 tons, the "K" class of 1,880 tons, and now the large "X" boats of which the particulars have not been published.

LITERATURE.

Automatic Telephone Systems. By William Aitken, M.I.E.E., A.Am.I.E.E. Vol. II. Auxiliary Services and Private and Branch Exchanges. London: Ernest Benn, Limited. 1923. [Price 35*s.* net.]

The first volume of this work, dealing with the general arrangements of automatic telephony as proposed by Strowger and others working on the same problem, was published two years ago, and a notice indicating the main purpose of the work appeared in our issue of December 30, 1921. Mr.

Aitken regrets that so long an interval has elapsed, and explains that the delay has been caused by the intricate nature of the diagrams, demanding expert draughtsmen of the highest qualifications. We may admit the sufficiency of the excuse for the plans and designs are of a highly technical character, and a reference to the earlier volume for interpretation of some of the more involved circuits may be necessary. The whole value of the book depends upon the correct and ready comprehension of these illustrations, that is to say, unless the diagrams tell the tale to the trained eye, the added description will be of little use. One may suspect that another cause that has operated to cause delay is the ingenuity that has been displayed in improving and simplifying the original arrangement for accomplishing a proposed object. Admittedly the continual accumulation of fresh matter has compelled the division of the second volume into two parts, and a third volume, which it is hoped will soon appear, has been found necessary to describe the full details. This may be an advantage in the end, but we imagine that this division will have the undesirable effect of increasing the cost of the entire work, not an unimportant matter in an expensive treatise, intended and adapted for the technical telegraphist.

In the former volume, the author traced the method and described the apparatus for making the process of automatic telephony generally available to the public. The plan was designed to provide similar facilities for all subscribers, and the complications arose from the large numbers who had to be accommodated. In the present volume, ingenuity is directed to supplying a great variety of contrivances to smaller numbers, who need private automatic installations differing in details for effecting particular purposes, or in fitting up private offices to villages and small communities, where considerable economies can be effected by modification of the general method. Greater ingenuity may be needed to meet some apparently simple public demand than in the repetition of the elaborate devices that are found necessary in large exchanges. The simplest example we can select from a number of instructive instances is that employed in speaking from a public call office, where payment has to be made before any conversation is permitted with a subscriber. The equipment must permit the Exchange to be called, provide means for informing the originator of the call that the line is disengaged, and that the called party is accessible. These preliminaries must be carried through previous to payment, and herein the arrangements need not differ from the ordinary automatic telephone. But the further arrangements must be of such a character that mutual conversation cannot be pursued till the fee is paid. The caller must not be allowed to speak to the called, but the response of the called party must be heard. We have no intention of explaining the mechanical operations by which the lifting of the called receiver is made to reverse the battery and short circuit the microphone, rendering the receiver inefficient, so that it cannot be used as a transmitter. The insertion of the coin, however, is sufficient to remove the short circuit and shunt, restoring normal conditions, and allowing the conversation to proceed. Other niceties may be added to inform the caller that the operation is proceeding, generally by means of a special tone signal being emitted when the receiver is lifted to reply. It is but a slight step to substitute for the coin box a metre, that would register with absolute certainty the number of calls made by any subscriber. Mr. Aitken gives a scheme and description of such a working apparatus, designed apparently by the Automatic Telephone Manufacturing Company. If the Post Office authorities were sincere in their desire to secure accuracy and eliminate the irritation and discontent experienced by those who believe themselves overcharged, there can be little doubt but that a suitable and trustworthy apparatus would be evolved. The scheme figured here seems "fool-proof" and "fraud-proof." The principal feature is the installation of a polarised relay, which functions in the same way as in the case of the coin box.

Of more importance are the devices employed in "Party-line Working" or providing a metallic circuit in which there are a plurality of substations. In this country not more than two stations have been used on automatic systems, but in the United States as many as 10 are frequently used. The method of calling in general use is the "harmonic-frequency" system, "the different bells on the circuit being adjusted and biassed to respond to a different frequency." A method of code ringing may supplement the frequency method, and polarised bells adapted to respond to positive and negative currents are found useful for four stations. A simple development is that introduced by Mr. Dean some years since, who proposed a party line system, that avoided earth connections, relays, adjustable springs or other apparatus that might be affected either by the resistance or the capacity of the line. Availing himself of the principle, that every reed has a natural period of vibration, he attached to each ringer or polarised bell a rod carrying a hammer of different weight and length. These rods were attached to an armature which again was connected to the frame by a short flexible spring. This simple arrangement has been superseded by a "harmonic-converter," provided with four pole changing vibrations each with a transformer and condenser to give the four frequencies.

A third section, and the larger part of the volume, is devoted to the mechanism of small installations in subscribers' offices to meet the manifold requirements of business. Such installations, though small, are of the utmost importance in ensuring the smooth working of affairs, for they are designed with the view of providing quick, accurate and secret intercommunication, while dispensing with the services of skilled attendance. Besides ordinary telephonic work outside the office, the private exchange renders special services by providing conference facilities, summoning officials in any part of the works, giving fire alarm, supervising watchmen, and in many other ways. The arrangements, however smoothly and unerringly they work, are of necessity complicated, but all are very clearly described and illustrated.

In the method of branch switchboards in use in this country, the Post Office has specified the nature of the traffic facilities that must be provided, and usually automatic switching is limited to local calls, an attendant completing the call to and from the main office. Such installations are usually under 15 lines capacity, and as often no trained operator is provided, the duties of supervising the connections and freeing the junctions for further calls are discharged by an irresponsible person, who will perform the necessary acts "when available and so disposed." It is easy to see that according to the relation of these small switchboards to existing telephones, the main service may be prejudiced either by unintentional oversight or from ignorance. When the manual operations are not correctly and promptly performed, trunks or junctions may be held idle for unnecessarily long periods, therefore from the postal service point of view, these private exchanges and similar additions to the ordinary public service should be entirely automatic in operation.

The schemes for carrying out the several projects contemplated are various, and their relative merits are probably to be decided only by actual practice; certainly from diagrams it would be both hazardous and invidious to suggest that any arrangement is preferable to another. But to possess the means of comparison between rival methods is of great interest, and sometimes it would appear as though a particular device that recommends itself on the score of compactness and simplicity in one direction, has gained that advantage as the consequence of added complication in another. It is safer and easier to commend those artifices which aim at the provision of greater facilities for isolated communities, where full installation with trained attendance might prove prohibitive on the grounds of expense. Messrs. Siemens have arranged a system, which seems admirably adapted for villages, where the demand for telephonic communication might be expected not to exceed 100 lines capacity. This equipment may be left unattended for a week, a system of alarms being arranged to call attention to any faults that may occur. Another scheme of like kind, of American origin, is well adapted for application to groups of farms and to fulfil the needs of a scattered population. The installation consists largely of party lines, which may be called by selective or code ringing, and the scheme is planned to work on the common battery system, but can be arranged for primary batteries.

A supplement is attached to the volume giving some additional information to that supplied in the sections of the earlier volume, but a few words of explanation might have been vouchsafed to make the object clearer.

BOOKS RECEIVED.

Railway Signalling, Mechanical. By FRAS. RAYNOR WILSON. London: Sir Isaac Pitman and Sons, Limited. [Price 2*s.* 6*d.* net.]

Friction. By T. E. STANTON, C.B.E., D.Sc., F.R.S. London: Longmans, Green and Co. [Price 12*s.* 6*d.* net.]

United States Geological Survey. Mineral Resources of the United States, 1920, Part I. By G. F. LOUGHLIN. II: 2. *Peat in* 1922. By K. W. COTTRELL. II: 33. *Coke and By-Products in* 1921. By R. S. MCBRIDE.

The Institution of Mechanical Engineers, Proceedings, January to April, 1923. London: Offices of the Institution.

Fundamentals of Welding. Gas, Arc and Thermit. By JAMES W. OWENS. First edition. London: Penton Publishing Company, Caxton House, Westminster, S.W. 1. [Price 50*s.* post free.]

Aeronautical Research Committee. Reports and Memoranda No. 832. *Report on the Influence of Calcium and of Calcium plus Silicon on Aluminium.* By J. D. GRAGAN, B.A. London: His Majesty's Stationery Office. [Price 9*d.* net; 9½*d.* post free.]

Technisches Hilfsbuch. Issued by Schuchardt and Schütte. Sixth edition. Berlin: Julius Springer. [Price 8*s.* 4*d.*]

UNDERGROUND TEMPERATURES AND VENTILATION.

IN 1916, a disastrous fire occurred at the Pennsylvania Mine, Butte, Montana, by which 21 men lost their lives. An enquiry, thorough and exhaustive, was set on foot immediately after the catastrophe, and Mr. Harrington, of the Bureau of Mines, was deputed to investigate the circumstances that contributed to the outbreak. In the following year a second fire, in which the loss of life was much greater, again directed public attention to the details of mining ventilation and the provision of efficient protection for the miners. Mr. Harrington necessarily extended the scope of his enquiry to include the conditions prevailing at North Butte, where the calamity occurred. Altogether the collection of data occupied two and a-half years, during which all the working places in four large mines were investigated and an examination, but little less thorough, was made of some twenty other mines. The publication of the discussion of the collected facts has been somewhat delayed, but is now issued,* and the Report deserves careful study. Probably no more thorough enquiry of existing conditions has been made, and the adoption of the recommendations in the mining industry at Butte is likely to prove beneficial to the workers and economical to the management. The conditions of mine working generally, however, depend so materially on the character of the output, the methods of working, the presence of gases, the depth and consequent temperature of the workings, that every mining engineer has to adapt known and recognised principles to the circumstances peculiar to the mine operated.

The metalliferous mines at Butte are peculiar. They yield copper in enormous quantities, but also give a fair yield of silver, zinc, gold and lead. The total value of the output up to 1918 was 1,400,000,000 dols., and the ore reserves blocked out indicate that for many years an annual production of 50,000,000 dols. can be confidently predicted under present prices. The distinguishing feature is the concentration of this wealth, present and prospective, within a very limited area. A circle having a radius of a mile and a-half embraces the whole. Some 15,000 men are actively employed below ground, in mines under separate ownership, but so closely located that it is possible to descend any one shaft and return by the shaft of an adjoining mine, since nearly all the workings are connected at various depths. The veins have a general dip of 70 deg. to 80 deg. from the horizontal, and run

* "Underground Ventilation at Butte," by Daniel Harrington. Bulletin No. 204 of the Bureau of Mines. Government Printing Office. Washington, U.S.A. 1923.

roughly parallel to each other, separated by some few hundred yards, hence the footwall of one vein is the hanging wall of another, and there are few shafts that do not intersect one or more veins. In this network of drifts and crosscuts the ventilation of the several mines is not independent, and when mine fires occur most of the mines receive heated, vitiated air from adjoining workings. In some cases, the entering air for ventilation has already done duty in another mine and has a very high temperature. Mr. Harrington confidently asserts that in nearly every Butte mine the air owes one or two degrees of increased temperature to heated air from an adjacent mine.

Broadly it might be urged that in metalliferous mines there is not the same necessity for maintaining an adequate supply of air at working faces as in coal mining or in gaseous mines. This rooted opinion explains in some measure the inattention bestowed on ventilation in planning small mines, in which shallow workings only are contemplated. This was certainly the case at Butte, where natural ventilation was held to be sufficient till the mines had penetrated below the 1,500-ft. level. This view is not shared by Mr. Harrington, though he admits that at those seasons of the year when there is considerable difference of temperature between that of the atmosphere and at the working face, the supply and circulation of air may be found sufficient, provided that the mine has at least one upcast and one downcast shaft, though under the most favourable circumstances there can be no efficient distribution of this entrant air about the place where it is most needed. The delivery of a current of air to workmen in crosscuts, stopes and blind ends, where high rock temperatures have the greatest effects, is of such importance that its necessity cannot be too strongly emphasised. We have learnt from the experiments of Dr. Leonard Hill and others that the actual pressure of the air coming on the skin exercises an invigorating effect. Exposure to moving air induces efficient respiration, promotes metabolism, and equips the body to resist disease. The dilution of the CO_2, content in the atmosphere, which has played so large a part in well meant schemes of ventilation, has not the importance that has been imagined. The enervating effects, noticeable when working in close and confined atmospheres, long attributed to the presence of carbon dioxide, are due to heat stagnation within the body, removable by increasing the air circulation. The knowledge of the linear movement of the air and of the readings of the dry and wet bulb thermometers, furnish more correct data for determining the efficiency of ventilation than do the most correct analyses of the composition of the atmosphere. Mr. Harrington, though he recognises the restorative effects of air in movement still clings to the theory that impurities in the air as CO_2, exercise the most pernicious effects. "Very small amounts of CO_2," he writes, "from 0·10 per cent. up, or a very slight oxygen depletion of 0·50 per cent. or over, quickly show themselves in depressing the worker, increasing perspiration, raising bodily temperature and lowering blood pressure." But he also notices that air in motion with a velocity of 400 ft. to 500 ft. a minute, though equally impure, had no ill effect, and he further observes that men will work without appreciable discomfort in air so charged with CO_2 and depleted of oxygen to such an extent that a match or a candle will not remain ignited, provided the air have a velocity no greater than 100 ft. per minute. This rate of movement would be barely sufficient to deflect a candle flame by an observable amount. The admission that the production of a current of air is "probably the most essential feature in the improvement of present conditions of ventilation" is a valuable testimony to the correctness of the conclusions deduced from modern enquiry and experiment.

The particular value of Mr. Harrington's contribution to the literature of the subject consists in his industrious observation and careful tabulation of results. His long stay in the mine and his study of the conditions that prevail at different seasons, enable us to see the problem of one particular mine in its entirety, and to comprehend the relations between the inherent evils and the means proposed to reduce them. It is easy to conclude that in mines of 1,000 ft. or less in depth the conditions of the outside air will exercise some effect, greater in winter than in summer, because the difference in temperature between that of the rock and of the atmosphere is greatest, and that as the mine grows deeper the effects at all seasons will become less perceptible. But Mr. Harrington's figures enable us to supplement such obvious conclusions by actual measurement of the amount of variation, thus supplying the accuracy that is needed to enable science to suggest mechanical improvement. The temperature of the solid undisturbed granite at the depth of 3,200 ft. is very approximately 100 deg. F., and at that level increases 1 deg. F. for every 100 ft. in depth. But where ventilation has brought large volumes of cooled air into contact with the rock, the rate of variation is uncertain, and continuous observation is the only means for supplying the data for the solution of the problem with which the engineer has to contend. The author gives as an illustration of the effect of the admission of cooled air, that in an old hole some 3,000 ft. deep, the granite temperature was only 69½ deg. F. as against 91 deg. F. in an advancing face in the same level, a few hundred feet distant. Other variables have lesser but quite appreciable effects. The temperature in the veins compared with that of granite, similarly placed, may differ by as much as 5 deg., and the zinc veins have a lower temperature than the copper, though both have a broken "sugar" quartz gangue carrying sulphide.

Passing over the effect of underground fires which obviously increase the temperature of a mine by an unknown amount, not only by radiation and convection, but by interfering with the ordinary processes of ventilation, a more subtle cause is found in the oxidation of timber and of sulphide ores, by which means there may be generated sufficient heat to cause fires. The temperature of air leaving abandoned workings where no fire existed, has been found to be 30 deg. higher than the rock temperature, and it is suggested that this increase is due to oxidation. Moreover, analysis of the heated air shows that oxygen is deficient and carbon dioxide in excess, indicating chemical reaction with probable release of heat. Laboratory tests favour the view here expressed, but as the experiments have been made only on a small scale it is not easy to institute comparisons between these and the results observed in mines.

The effect of friction in heating the air underground is a considerable source of rising temperature that can be easily underestimated. Contact with heated rocks would, of course, increase the heat of the ventilating currents, but examples are given where the heightened temperature could not be attributed to this cause. Actual measurements show that it is possible for air to rise in temperature 6·5 deg. while traversing 300 ft. of 10-in. canvas pipe, the velocity being 4,800 ft. per minute. Here the increase is more than 2 deg. per 100 ft. travelled, or reckoned in time while travelling 1¼ seconds. This fact points very decidedly to a limit of travel, for if the air at point of discharge is to have a temperature of 80 deg. or less, the length of travel must not exceed 2,000 ft. at ordinary mining velocity. The spraying of water into the intake lowers the temperature rapidly but increases the relative humidity. On the other hand the introduction of elbows and bends in the pipe adds very materially to the temperature. Mr. Harrington's measures enable us precisely to see quantitatively the value of piping in promoting ventilation and assisting the distribution of currents, but the effect that the generation of heat has upon the temperature of drifts and crosscuts cannot be separated from that of other variables.

Among these variables the author is inclined to put the movement of the ground, but this we think, is rather of theoretical than practical interest. At Butte, where the veins are much inclined to the horizon there is a tendency for all the ground between the mines to settle. The excessive movement is indicated by the amount of work necessary to keep the shafts open, the upper part of a shaft often moving its full width in two or three years. The actual movement of a mass of ground weighing hundreds of millions of tons must generate heat, though the movement of material is slow. On the other hand the dissipation of heat in the same time is not negligible. Of more utility and importance it seems to us are the actual measures of increase of temperature due to the firing of shots. In one of the lower levels a round of fourteen 5 ft. holes, drilled in the solid granite face, was charged with about 70 lb. of 40 per cent. gelatine explosive and fired by electricity. The temperature of the rock and in the holes was 101 deg. F., and that of the air in which the men worked was 83½ deg. The thermometer readings taken three minutes after the explosion, declared a rise of 14½ deg. This increase must be divided between the heat liberated by the explosive, and that arising from the interruption of ventilation, and consequent accession of heat from the rock, but the latter was probably small, as there was only an initial difference of 18 deg. operating through a period of three minutes. Since 7,000,000 lb. of similar dynamite are fired annually the effect can hardly be negligible, especially in ill-ventilated blind ends.

The percentage of humidity in mining air is always high, and is a factor of great importance, as it largely determines the comfort and health of the workpeople. The mean dry bulb temperature of all the stations visited was 78·8 deg., and that of the wet bulb, two degrees lower, giving a relative humidity of 91·3 per cent. This seems high in presence of the thermometer readings, but careful enquiry elicits the fact that humidity above 95 per cent. does not prevent a place being rated as fairly comfortable, if coincidently the temperature is less than 80 deg. On examination it appeared only 22 places had a relative humidity less than 85 deg., and of these 21 were reckoned comfortable. But of 34 places having a humidity less than 90 per cent., 8 were classed as uncomfortable, and of 73 stations in which the humidity exceeded 95 per cent., 46 were condemned as uncomfortable. These figures show fairly conclusively that relative humidity is a decisive factor only when it exceeds 95 per cent.

It is permissible, therefore, to use water largely to lower the temperature of so-called dry air, and the action of water as "drippers" or in the form of spray is most effective. Where water flows on the floor or stands in a pool its effect is hardly measurable. The invisible moisture in downcast shafts plays a far more important part. Dry air moving in downcast air currents at 700 lin. ft. per minute, increases in humidity at the rate of 1·2 per cent. for every 100 ft. of downward travel, until it exceeds 70 per cent. Very little air leaves the downcast shafts at the 2,000 ft. level at a lower relative humidity, and at all stations below 2,500 ft. the relative humidity is practically constant, quite irrespective of the dryness of the air at the surface. In slow moving or stagnant air, as in most blind ends the increase of humidity is very rapid, the rate being from 5 per cent. to 10 per cent. per 100 ft. of travel till 90 per cent. is reached. Air brought through pipes though heated by travel and nearly saturated by moisture would be still of advantage to the miners if the air movement be continued right up to the working face. Unfortunately the air motion falls off rapidly after leaving the delivery pipe. A case is quoted in which air, travelling 5,000 ft. per minute, was allowed to discharge 60 ft. from the breast, yet on reaching the workers at that point no motion could be detected. When the air was allowed to escape 20 ft. from the breast it still possessed on arrival the very beneficial velocity of 300 ft. per minute. Where canvas tubing is used in levels as the conductor, the point of discharge need never be more than 30 ft. from the face, as a 50 ft. length can be easily detached before blasting if any injury is anticipated.

Canvas tubing in connection with fans and small electric motors seems destined in the future to play a large part in ventilation, since it furnishes a simple mechanism for relieving excessive oppression in blind ends, and provides mining working places with safe, comfortable and healthful air conditions. Experiments have shown that the decrease in relative humidity in air carried in such conductors at high velocity was as much as 5 per cent. per 100 ft. of travel. By reason of its flexibility, elbows and sharp curves that exercise so great an influence on the temperature of the air conveyed, can be avoided and the apparatus used for directing streams of air on places difficult of access. Against these advantages have to be placed the rapid decay of the fabric in stagnant humid air, a ready disintegration from the

acids found in mine water, and a dangerous inflammability. These drawbacks will no doubt be overcome by impregnating the material with some substance that will withstand decay and fire, and enable it to resist weak acid water. For canvas tubing possesses the great superiority over galvanised iron piping, its one rival, that the friction is much less, implying a smoother internal surface, since irregularities, whether in shafting or in pipes, seriously diminish both the velocity and the volume of air delivered. In one of the deepest shafts a smooth lining of boards and solid concrete was substituted for rough timbering, with the result that with the same ventilating equipment the air flow was increased from 55,000 cub. ft. to 85,000 cub. ft. per minute. In another experiment in which the object was to determine the velocity of the air, it was found that the same fan and motor working on a smooth lining increased the velocity from 1,350 ft. per minute to 3,650 ft. per minute. Tests were also made on three shaft models, each on a scale of $\frac{3}{4}$ in. to a foot, one representing the usual timbered cross section of the mine, another precisely similar in size but lined with boards ensuring a comparatively smooth surface, while the third was of solid concrete with smooth interior surface and circular cross section. They were placed side by side in an underground raise with a small fan that could be connected through a flexible hood to the top of each to pull air through it. Representing the volume of air pulled through the timber-lined rectangular shaft by unity, it was found that the same power would pull 1·91 volumes through the smooth lined rectangular shaft, and 3·31 volumes through the shaft of circular section. The water gauges were respectively 3·2, 2·7 and 2·1; the power ratio for equal volumes of air pulled were as 1·00, 0·277 and 0·091.

Several kinds of smooth lining have been tried, and the increase of cost is necessarily considerable, the expense rising from 8 dols. to 20 dols. per linear foot according to the material used. But when compared with the waste that is the consequence of maintaining unfavourable working conditions underground, such expenditure is amply warranted. The waste is shown in various ways, not least in the extremely high labour turnover where the conditions of working are injurious to health and comfort. At Butte, where serious attempts have been made, and not unsuccessfully, to improve the underground conditions, this turnover in the years 1916-18 averaged 500 per cent., per year, frequently running well over 100 per cent. per month. Where the working force is approximately 13,000, not less than 65,000 have to be recruited to maintain this figure at a constant level. Since the management estimates that the cost of replacing each working unit varies from 10 dols. to 25 dols. it may be computed that a million dollars per annum is lost to the undertaking from this cause. The distressing conditions prevailing underground form the main cause of this frequent change of employment. In particular mines, when an unwise parsimony has curtailed initial expenditure, the financial conditions are liable to be far worse. Mr. Harrington describes a section of a mine having an unusually poor ventilation with high temperature and humidity, where it was necessary to bribe the workmen to continue work by the payment of a bonus of 25 cents per day over the regular wage and to reduce the length of the shift from eight hours to seven hours. Only one half of the men worked at a time, the other half sat under a compressed air hose to cool and to recuperate. The maximum efficiency here of a man, necessarily of exceptional endurance, was probably not more than 30 per cent.

Of course there are plenty of instances where increased ventilation has been followed by greater output of work and diminished exertion, but unfortunately the conclusion must be drawn that self-interest is not sufficient to induce owners and proprietors to instal an adequate equipment, and, therefore, legal enactments become necessary to compel the provision of a minimum circulation of air underground. The stipulated quantity of air per man or per animal, differs in different countries, and is generally made dependent on the temperature. The different amounts, varying from 100 cub. ft. to 300 cub. ft. per minute, point to the uncertainty which prevails concerning the cause and amount of heat fluctuation. By calling attention to the operation of the various factors and the probable effect of each, Mr. Harrington renders an essential service and places the theory of mine ventilation on a more stable foundation. One general conclusion at which he arrives is that the amount of air required by statute is sufficient, if the distribution is efficiently regulated. To aid in securing such a desirable result he rounds off his admirable work by giving some useful practical recommendations, suggested by his experience in different methods of mining. Among these, none strikes us of more importance than the insistance on the provision of continual supervision by a competent official, armed with plenary authority to enforce obedience and ensure the mechanism supplied being used to its full capacity. "Old timers, both bosses and miners," who have lived through conditions less favourable than those now existing, but still far behind what economy and humanity alike demand, ridicule and contemn all efforts to make ventilation more efficient. "It is practically certain," says the author, "that little or no progress towards improvement will be made, until reactionary bosses have been removed," and he speaks with intimate knowledge of mining character. To deal with these uncouth elements the ventilating superintendent will need tact as well as science, and further, he may find the interference of trade unions as deadly a foe as the prejudice and indifference of the old miners to what is designed for their benefit. We are told of a miner who ingeniously fixed a piece of canvas across a drift so as to deflect the air into his stope and give him a reasonably comfortable working place. A workman, running an electric motor on the drift, tore the canvas down and threatened a strike if the motormen were compelled to pass through canvas brattices across drifts. The road to progress is beset with many hard places that delay and discourage the ardent reformer.

NOTES ON NEW BOOKS.

The principles of electric current generators and motors were fairly well understood two decades ago, and so little, comparatively, has been added of late to our knowledge of these problems that there is more demand at present for books on structural details than on the principles of the subject. With increased experience it becomes more easy to separate the essential from the unessential and impracticable, and the author of a text-book should profit from the mature experience available. Dr. Ing. K. Hoerner has done so, we believe, in his "*Grundzüge der Starkstromtechnik für Unterricht und Praxis*" [Berlin: Julius Springer; price 4*s.* 2*d*]. The 257 pages of the volume, which is illustrated by 319 text-figures, are written for the student and young electrician and are noteworthy for the general treatment. Hoerner aims at giving simple explanations without having recourse to more than indispensable formulæ. There is a risk in that. Analogies may be pushed too far, and the author may become prosy. Dr. Hoerner can certainly not be charged with being prosy and with filling pages with unnecessary words, and he warns his readers from the beginning against misleading analogies. His book seems well adapted to the standpoint of the technologist, who does not command the mathematical knowledge which a theoretical study of these problems would require.

HEAVY labour charges and the high cost of fuels and raw materials generally are, in no small degree, responsible for the keen competition which exists among manufacturers at the present time. Strict economy, with efficient working and maximum output are recognised essentials to success, and with these in view, Professor W. Trinks, of the Carnegie Institute of Technology, makes a complete survey of problems connected with steel annealing and reheating furnaces in his book "*Industrial Furnaces*," Vol. I. The price is 22*s.* 6*d.* net, and the publishers are Messrs. John Wiley and Sons, New York, and Messrs. Chapman and Hall, London. The author confines the limits of the first volume to a discussion of the principles which determine the utilisation of heat when once generated. Furnace design is first outlined, and then follows an interesting section on the heating capacity of furnaces. The bulk of the work, however, is devoted to such subjects as fuel economy, heat-saving appliances, strength and durability of furnaces—all questions of the utmost importance. Loss of heat in all its forms is dealt with in great detail, and the whole matter treated from a mathematical point of view; formulæ are quoted and numerous examples given to demonstrate their application. The calculated "balance sheet" of a typical oil or gas-fired "in-and-out" forge furnace shows that the heat taken up by the steel is only about 20 per cent., the rest being stored in the brickwork or lost by radiation and incomplete combustion; more than half the total heat generated escapes with the flue gases. This latter fact clearly shows that the use of heat-saving appliances is a question of vital importance. Continuous and regenerative furnaces are then described in great detail, and the immense advantages gained by their use, are well set out, many helpful examples being worked out. A short description of waste-heat boilers is given at the end of the chapter. The section on strength and durability deals in a very thorough manner with constructional details, each portion of the furnace being considered separately. The book closes with a chapter on the movement of gases within the furnace, the author aiming at obtaining correct internal circulation and determining the most advantageous location of flues and stacks. It is stated in the preface that "none of the theories offered are untried; all have been tested and proved in actual furnace practice." This is very evident, and the book is worthy of deep study; eminently scholarly and well thought out, it is obviously not meant to be used as a casual reference work. The absence of tables constitutes a pleasing feature, graphs invariably taking their place. In a few cases, however, the scale used is hardly large enough for comfortable examination. The numerous illustrations, too, are rather small, but, generally speaking, are clear and well defined.

The growing keenness in industrial competition, and the consequent necessity of cutting production costs to a minimum, has led during recent years to considerable developments in the mechanical handling of material not only in workshop and factory but also in quarry and mine, and in connection with excavation work of all classes. Mechanical conveyors, mechanical elevators and other mechanical methods of transferring material of all descriptions from one point to another in a minimum of time and at a minimum of expenditure, are being employed to an increasing extent in almost all industries both in this country and elsewhere. For this reason Mr. F. V. Hetzel's book on "*Belt Conveyors and Belt Elevators*" is of particular interest at the present time, and should find a useful place in the literature of practical engineering. The design and installation of belt conveyors is essentially a specialised branch of engineering, and it is a branch that heretofore does not appear to have had a very extensive range of text books devoted to it. Mr. Hetzel deals with his subject in a comprehensive and practical manner, and supplies a great deal of valuable data which cannot fail to be of interest and of real utility to all engineers engaged in the design or installation of machinery of the type in question. Practically every aspect of the subject is covered in a manner which is at once simple and direct, the treatment being practical and the few mathematical analyses introduced being set out with unusual lucidity and directness. A large amount of valuable data bearing upon the subject, and derived from the results of actual practice, is given in the numerous tables embodied in the volume. In some instances such data might, with advantage, have been presented in graphical form, but this is a minor defect. The book is well illustrated with photographs and drawings. In addition to treating of the design of belt conveyors for a wide range of material under differing conditions and the installation of machinery of this type, Mr. Hetzel devotes considerable space to the operation and maintenance of plant of this description under a variety of circumstances as met with in practice, and this section of the volume should be of material assistance to engineers who are responsible for the upkeep and operation of belt conveyors in addition to those engaged on their design and installation. The author's analysis of the conditions under which belt conveyors and elevators can be used to advantage, and of the savings in production costs which can often be attained by their use, should have the effect of inducing many manufacturers who at present employ manual methods of handling their materials carefully to consider the advisability of adopting the mechanical transport which is afforded by plant of this type. The book is published in London by Messrs. Chapman and Hall, Limited, 11, Henrietta-street, Covent-garden, W.C.2. Price 25*s.* net.

Children of all ages, and those who like to keep young as long as possible would lose a great deal of the pleasure of life if by some strange revolution railways ceased to help the world along. There is a fascination in the passing train, with its huge weight and powerful locomotive, and the rush as it approaches and travels on out of sight, which does not attend any other form of transport, or possibly any other development for which man is responsible. The working of the signals by an invisible agency, and their return to a position of

protection when the train is passed, appeals to the imagination as organisation which is well nigh perfect. Formerly it was difficult for young people to secure much information on railway working, and the few books available were rather too advanced for them, and not sufficiently so to be of any great value to the professional railway man. In later years we have improved on these conditions. The specialist is catered for in a number of excellent text books which may be made of real assistance to the serious student in his work, while the youth of the population has the choice of several volumes which will interest them even if they have no idea of finding on the railways a career for life. Among the best of such books may we place Mr. J. F. Gairns' "*Railways for All*" (Messrs. Ward, Lock and Co., Limited, London; 6*s*. net). Mr. Gairns is a well-known writer on locomotive matters, and these occupy a large portion of his work, which is as it should be, because the locomotive is the centre of interest in youthful eyes. A great deal of other information is, however, also compressed into the pages. In many cases we fear the condensation has been too great. The book is excellently printed and is replete with good illustrations to which, however, somewhat inadequate reference is made in the text. It would form an excellent gift.

Candidates for the degree of B.Sc. in engineering will find extremely useful the treatise on "*The Properties of Engineering Materials*," by Mr. W. C. Popplewell and H. Carrington, of the College of Technology, Manchester. The practitioner will also find the volume valuable as a work of reference. Just about one-half the text is devoted to the theory of stresses and strains. The range covered is somewhat more extensive than customary, and includes sections on the strength of plates supported all round, on the effect of curvature in altering the stress distribution on the cross-section of a beam, and also we are glad to note an account of the highly ingenious method of determining the torsional stresses in odd sections which was originated by Professor Batho in 1915, and improved and extended subsequently by Dr. Prescott. Numerous examples will show the student the kind of question he is likely to encounter in examinations. Each new problem, however, is dealt with by some special device, and general methods applicable to all problems are hardly touched upon. Indeed there appears to be no mention of Castigliano's comprehensive theorem, nor are the general equations of the mathematical theory of elasticity formulated. Of course, this procedure is usual, but some day an examiner may arise, who is more concerned with a student's knowledge of principles than with his skill in manipulating formulas, and then trouble may be expected. In the present case the student, from the figures given on page 67, would be justified in believing that the T and L shown offered the same resistance to a bending moment acting perpendicularly to the table of the T and the corresponding leg of the L. The point is not an academical one by any means. Indeed, a few years back the confusion of mind amongst those nurtured on the popular text books, gave rise to conflicting interpretations of some of the London County Council rules for reinforced concrete. The second half of the book is devoted to the physical properties of materials of construction and to a description of the machines used in testing them. This will be found very useful for reference purposes, and is clear and reasonably complete. In the chapter dealing with the factors of safety, however, far from sufficient emphasis is laid on the empirical factor involved. It is no doubt true that in many cases a factor of safety for steel subjected to shocks should be as high as 12, but in guns which are subjected to particularly violent shocks it is often not much above 2. The calculated working stress on ordinary chain links, again, comes out at about 30,000 lb., and such links are generally constructed merely of good wrought iron. In the case of bridges there is, of course, the added practical impossibility of calculating the stresses with any great degree of accuracy, a circumstance which led M. Rabut to what we have always considered the illegitimate conclusion that the Vierandell truss was superior to a braced truss because there was with it a better agreement between calculation and observation. The treatise is capitally printed and 260 illustrations are included in the text. "Art paper" has been used for the process blocks, which adds greatly to the cleanliness and sharpness of the reproductions. The publishers are Messrs. Methuen and Co., Limited, and the price of issue is 28*s*.

STEEL-FRAMED BENDING PRESS.

The use of steel plate and standard sections in the building up of the frames of certain classes of machines is growing in popularity, because of the many obvious advantages it has when comparatively light constructions have to withstand heavy stresses. An example of considerable interest is to be seen in the plate bending press which we illustrate on this page. This machine is one of the new standard productions of Messrs. Rice and Co. (Leeds), Limited, of Neville Works, Elland-road, Leeds. It is intended for the cold-bending of plates, 14 ft. width and up to ¾ in. thick—a field of great service. With thicknesses of this nature it is frequently possible to eliminate some of the rolled angles in the structures manufactured, as the plates can be bent to right angles or to other inclinations in the machine. In addition to that use there are many shapes to which steel can be bent cold, such as those of the scoops for feeding the retorts in gas works, in the manufacture of the steel boilers which are built into the flues of kitchen fires and also in the production of tanks.

Fig. 1 shows the general appearance of the machine, and the drawings Figs. 2 and 3 give further indication of the construction. The base is made of two strong channels effectively stiffened, on the side subjected to tension when working, by a strong plate which is riveted to them. Upon this base are three cylinders which are connected to the pipe system so that pressure can be put under the rams of the centre one, or the two outside ones, or all three together. The opening of either or both of the two valves, shown at the side of the plant is thus all that is necessary to change the power of the machine, the actual loads being 85 tons, 170 tons and 255 tons. With such a possible variation in power the machine is capable of extended application in many classes of work. The moving table and the top are built up with steel plates and carry the two angle dies used in the bending process. There are heavy columns in the form of bolts, for the side members of the frame, and one of them is hinged at the foot so that it can be swung out of position for the removal of square boxes made from flat plates by making the right-angled bends for the corners in succession in the press.

While the capacity of the machine is limited in width by its dimensions, it must be noted that thicker plates than those referred to can be bent if the width is not so great. The machine illustrated is of a size for which there is a great demand, but others of similar type for different capacities are also manufactured, in fact they are obtainable to deal with plates of a very large range in size or thickness.

STEEL-FRAMED PLATE BENDING PRESS.

CONSTRUCTED BY MESSRS. RICE AND CO. (LEEDS), LIMITED, ENGINEERS, LEEDS.

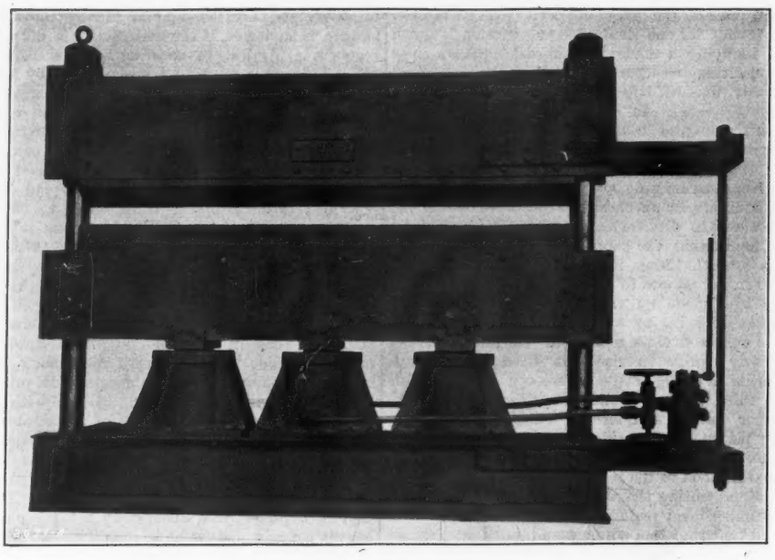
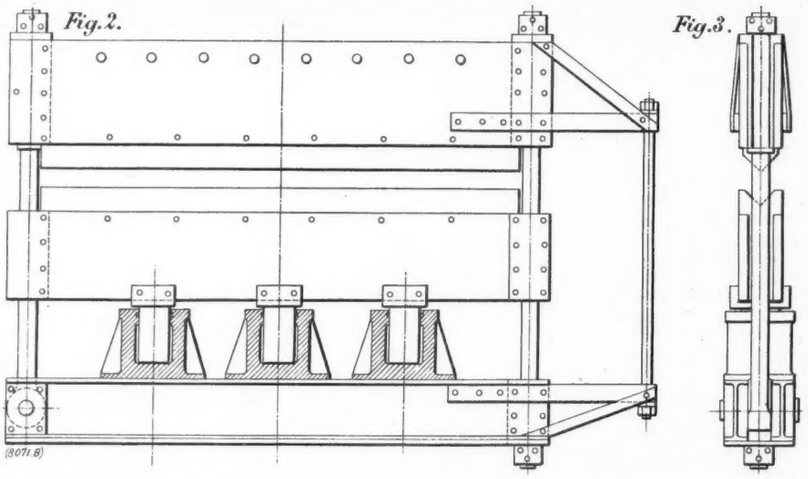


Fig. 1.



Automobile Bibliography.—The Public Libraries of the City of Coventry claim to have the largest collection in this country, as they quite properly should, of literature devoted to automobile subjects. A little bulletin has just been published by the Libraries Committee dealing with one section of this material and lists all books, pamphlets and articles to which reference may be made at the libraries, published subsequent to 1910. It may be mentioned that at the libraries a large number of periodicals and transactions of societies are regularly received, and all articles of permanent value are indexed for the convenience of searchers for information. The information file thus compiled consists of upwards of 7,000 entries, the list being divided into 55 headings. The facilities for search and references thus provided are clearly on a very considerable scale and of much value.

THE STROUD SYSTEM OF TEACHING DYNAMICS.*

By Professor Sir JAMES B. HENDERSON, D.Sc.

VERY few teachers ever have the chance of noting the advantage or disadvantage of a change introduced into their methods of teaching, and of profiting by the same. I desire now to put on record the results of such a change and the method by which they were attained.

The number of systems of teaching dynamics is great, and still the results are deplorable as judged by the knowledge possessed by the average engineer some years after he leaves college. Teachers are either biassed in favour of the Gaussian system or the Perry system, or some other system of their own, and are loath to change because they can train their students to solve the necessary problems, and if a mistake is made by omitting g or some other quantity it is merely a mistake and costs nothing. It is not so with the poor student, however, when he is launched on the world without his teacher to help him. The first essential with the engineer or naval officer in his calculations is accuracy, and the young engineer is lucky if his mistake only costs his firm a few shillings; he then begins to think for himself and to realise what accuracy means in practice, not only numerical accuracy but a certainty that every factor in the problem has been considered, and given its due weight. The Stroud system, with which these experiments were made, is a valuable aid in this respect.

This system is not new; it was devised in the eighties of last century by that versatile genius Professor William Stroud, of Leeds University, the best teacher of physics the writer has known, a most ingenious inventor, and an outstanding figure in the branch of physical optics. It was taught by Professor Stroud until his retirement about 1910. It has been partly adopted in some text books, but the full system in all its essentials has not yet been published. It is not antagonistic to the Gaussian or any other logical system of teaching dynamics but it embraces all such systems and they become special cases of the Stroud system. Its success depends upon a number of artifices which very greatly help the engineer and experimental worker.

The writer first became acquainted with the system in 1894, when he went as assistant to Professor Stroud in Leeds. He adopted it immediately and taught it to students of engineering and physics in Leeds and later in Glasgow University, but he did not appreciate its full value until after he joined the staff of the Royal Naval College, Greenwich, in 1905, and undertook the instruction of the advanced classes of lieutenants, going through the "dagger" courses in ballistics and thermodynamics, who had been trained for years on the Gaussian system and yet could not solve practical problems in dynamics with ease or certainty. These officers were introduced to the Stroud system and appreciated its advantages immediately. So much so that the writer approached the instructors who had taught these officers dynamics as sub-lieutenants, Instructor Captain John White and Instructor Commander Hartley, with the result that these two enthusiastic teachers both adopted the system at once and, when the new classes of students reached the writer, two years later, the improvement was most marked, and all the former trouble with units had disappeared.

I have been thanked by many of the present naval constructors for introducing them to the system when studying at Greenwich after years of study with other systems at the Dockyard Schools and Keyham College.

The Stroud System.—Definitions:—

(*a*) *Ratio.*—A ratio is a comparison between two quantities of the same kind or dimension, such as 2 ft. to 3 ft., and is written:—

$$\frac{2\text{ ft.}}{3\text{ ft.}} = \frac{2}{3}$$

(*b*) *Rate.*—A rate is a comparison between two quantities of different dimensions or kind, such as 2 ft. to 3 seconds and is written:—

$\frac{2\text{ ft.}}{3\text{ sec.}}$ or 2/6*d.* per pound, which may be written $\frac{2/6d.}{\text{lb.}}$

A rate takes its name from the denominator, thus velocity is defined as the time rate of change of position and has the dimension $\frac{\text{ft.}}{\text{sec.}}$; acceleration is defined as the time rate of change of velocity and has the dimension $\frac{\text{ft.}}{\text{sec.}^2}$, &c.

Convention 1.—A convention in the Stroud system is always to write rates as we write ratios, *i.e.*, in fractions, but with the labels of the units or kind attached and never to separate the number from the label of the kind unless the kind cancels out. Write $\frac{2\text{ ft.}}{3\text{ sec.}}$ and not $\frac{2}{3}$ ft. per second.

Terminology.—Physical science generally might well be called the science of rates because it deals with quantities of many different dimensions, namely the fundamental dimensions mass, length and time, and dimensions which are combinations of these, such as

$$\frac{\text{ft.}}{\text{sec.}^2},\ \frac{\text{lb. ft.}}{\text{sec.}^2},\ \frac{\text{lb. ft.}^2}{\text{sec.}^2},\ \&c.$$

It is common to read in text books on dynamics, in works on physics by the most distinguished physicists and in engineering and technical literature a problem in dynamics stated in part, "let m be the mass in pounds (or some other unit), t be the time in seconds," and so on. Why should it be necessary to state the unit in which the mass, time, length, &c., is to be measured? It is necessary because of the limitation imposed by the Gaussian (or other) system of teaching dynamics.

The Stroud system eliminates the necessity for the specification of units in the statement and setting out of the general problem, and these have only to be considered in the numerical calculations.

The system therefore involves another convention:—

Convention II.—Let each symbol in a problem not only represent the quantity numerically, but also contain the units, *i.e.*, let it represent the quantity wholly. Thus speak of a mass m, a time t, a velocity v, an acceleration a, a force F, work W and so on; not of a mass m lb., a time t seconds, a velocity v ft. per second, an acceleration a feet per second per second, a force F lb. weight, work W ft.-Lb., and so on. Note the resulting saving of space involved, which is of some minor importance. When one of these quantities has to be stated numerically, of course, the label then must be attached, but so long as the problem is general the label is embraced by the symbol. When a symbol is used to denote a dynamical quantity, then the symbol represents the quantity both in respect of units and the number of these units, that is, completely without further limitation or specification.

The science of dynamics is therefore, by Stroud's system, accurately depicted on paper as a science of rates, not as a science of pure numbers, and the solver of a problem is at every moment working on paper numerically and unitally, not, as in the old system, working numerically on paper and unitally in his head.

Kinematics.—The kinematic formulæ are:—

$$v = \mathrm{V} + a\,t$$

$$s = \mathrm{V}t + \frac{1}{2}a\,t^2$$

$$v^2 = \mathrm{V}^2 + 2\,a\,s$$

Provided that by unit velocity we mean the velocity with which unit distance is traversed in unit time and so on.

The first is merely a statement of the definition of acceleration in the form of an equation. The second is a similar statement that the space is the average velocity multiplied by the time, and the third is derived from the first two by eliminating t. All these are true in all units provided the symbols contain the units, and it is unnecessary to limit the equation in any way by specifying the units.

Example 1.—A train starts from rest and acquires a speed of 60 $\frac{\text{miles}}{\text{hr.}}$ in 10 minutes. What is the acceleration?

$$a = \frac{60\ \frac{\text{miles}}{\text{hr.}}}{10\text{ mins.}} = 6\ \frac{\text{miles}}{\text{hr.} \times \text{min.}}$$

This is a complete answer to the problem unless the acceleration is wanted in some particular unit, say ft./sec.^{2}, then

$$a = 6\ \frac{\text{miles}}{\text{hr.} \times \text{min.}} = 6\ \frac{5280\text{ ft.}}{60 \times 60\text{ sec.} \times 60\text{ sec.}}$$

$$= \frac{5280}{36000}\ \frac{\text{ft.}}{\text{sec.}^2} = \cdot 146\ \frac{\text{ft.}}{\text{sec.}^2}$$

Example 2.—A train starts from rest and acquires a speed of 60 $\frac{\text{miles}}{\text{hr.}}$ in 5 miles, what is the acceleration in ft./sec.^{2}?

$$a = \frac{\left(60\ \frac{\text{miles}}{\text{hr.}}\right)^2}{2 \times 5\text{ miles}} = 360\ \frac{\text{miles}}{(\text{hr.})^2}$$

$$= 360 \times \frac{5280\text{ ft.}}{3600 \times 3600\text{ sec.}^2} = \frac{5280}{36000}\ \frac{\text{ft.}}{\text{sec.}^2}$$

$$= 0{\cdot}146\ \frac{\text{ft.}}{\text{sec.}^2}$$

Force.—Newton's first law defines force. Newton's second law gives a means of measuring force. The second law stated in the form of an equation is

$$f = k\,m\,a$$

in which k is a numerical constant depending upon the definition of unit force.

Definition of Unit Force.—Unit force is defined as that force which, acting on unit mass gives it unit acceleration. With this definition $f = m\,a$. The definition says nothing about the particular unit employed, yet the majority of the text books on dynamics proceed to limit this definition, and it is at this point where most of the misunderstanding and confusion in dynamics arises. The books on the Gaussian system state that the unit of mass is a pound or a gramme, and Professor Perry made it a slug or 32 lb. Why limit the definition? It is true in all units and is above units. Any mass may be used as a unit of mass, and any acceleration as a unit of acceleration, and since the one multiplied by the other must, by definition, give us a unit of force, there must be an infinite number of these units.

Units of Force for which we have Names.—We have only names for a few of the infinite number of units of force:—

$$\text{Poundal} = 1\text{ lb.} \times 1\ \frac{\text{ft.}}{\text{sec.}^2} = 1\text{ lb.} \times\ \frac{\text{ft.}}{\text{sec.}^2}$$

Poundweight = force of gravity on 1 lb. mass at Greenwich, and by experiment the acceleration produced by the weight if the mass is allowed to fall is 32·2 ft./sec.^{2}, hence

$$1\text{ lb. weight} = 1\text{ lb.} \times 32{\cdot}2\ \frac{\text{ft.}}{\text{sec.}^2}$$

NOTE.—To distinguish pounds weight from pounds mass, Professor Stroud writes the former always with capital letters, hence

$$1\text{ Lb.} = 1\text{ lb.} \times 32\text{ ft./sec.}^2$$

$$1\text{ Ton} = 1\text{ ton wt.} = 1\text{ ton} \times 32\text{ ft./sec.}^2$$

$$1\text{ Dyne} = 1\text{ gramme} \times 1\ \frac{\text{cm.}}{\text{sec.}^2}$$

$$1\text{ Gramme} = 1\text{ gramme wt.} = 1\text{ gramme} \times 981\ \frac{\text{cm.}}{\text{sec.}^2}$$

$$1\text{ Kg.} = 1\text{ kg. wt.} = 1{,}000\text{ gramme} \times 981\ \frac{\text{cm.}}{\text{sec.}^2}$$

$$1\text{ Lb.} = 1\text{ Slug} \times 1\ \frac{\text{ft.}}{\text{sec.}^2} = 32\text{ lb.} \times\ \frac{\text{ft.}}{\text{sec.}^2}$$

Example.—A train of mass 100 tons acquires a speed of 60 m.p.h. in 10 minutes. What is the average force?

$$f = m\,a$$

$$= 100\text{ tons} \times \frac{60\text{ miles}}{\text{hr.} \times 10\text{ min.}}$$

$$= 600\ \frac{\text{tons} \times \text{mile}}{\text{hr.} \times \text{min.}}$$

This is a complete answer to the problem, unless the answer is wanted in some particular unit. Suppose the answer is wanted in tons weight. Various methods of conversion may be employed, but it is the writer's practice to multiply by the unit required and divide by its dimensional equivalent and then cancel all units except the one required, thus:—

$$f = \frac{600\text{ tons} \times \text{miles}}{\text{hour} \times \text{min.}} \times \frac{\text{Tons}}{\text{ton} \times 32\ \frac{\text{ft.}}{\text{sec.}^2}}$$

$$= \frac{600 \times 5280}{60 \times 60 \times 60 \times 32}\ \text{Tons} = \frac{11}{24}\ \text{Tons.}$$

It is unnecessary to develop the application of this system to all the definitions of dynamics, so I shall conclude by showing some of its practical advantages.

It is a common experience in physical and engineering laboratories, and in the drawing offices and test-houses of commercial engineering firms for a worker to present a result which is palpably wrong, and on having his attention drawn to the fact he will probably reply after reflection, that he has omitted one of his measurements entirely, say the diameter of a wire, or he has omitted g, or will give some equally foolish excuse. One great advantage of the Stroud system is that it makes such an omission impossible, because if the worker omits any factor having dimensions he cannot get the dimensions of his result correct, and has therefore to look for his omission.

The greatest difficulty in teaching and understanding dynamics arises from the fact that the terminology is one of every day use, and the student starts his studies heavily handicapped by the preconceived ideas he has absorbed as to the physical meaning of the terms employed, such as mass, weight, force, momentum, energy and so on, and he finds great difficulty in abandoning these preconceived ideas and in replacing them by the scientific definitions.

The difficulties of the young student are almost entirely due to these preconceived ideas, and it should be the effort of every teacher to make the student think of the scientific definition of the term whenever he writes the term down. Every time he writes down pounds he has to ask himself "do I mean pounds mass or pounds weight?" The Stroud system does this automatically because it is almost impossible to write down the number and the unital label without thinking of the definition.

Another advantage is that it enables the experimental worker to shorten his calculations by employing mixed units without reducing them all to the ft.-lb.-sec. or cm.-grm.-sec. system. If he measures one factor in millimetres and another in feet, depending upon the measuring instrument employed, these are so entered in the equation.

An example will show the impossibility of omitting an experimental factor, and the ease of working with mixed units. A spiral spring of 20 turns of helical diameter D = 2 in. of wire having a diameter d = 2 mm. is loaded with 100 Lb.; calculate the spring deflection if C = 12 × 10^6 Lb./in.^{2}

$$s = \frac{8\,\mathrm{W}\,\mathrm{D}^3\,\mathrm{N}}{d^4\,\mathrm{C}} = \frac{8 \times 100\text{ Lb.} \times 8\text{ in.}^3 \times 20}{16\text{ mm.}^4 \times 12 \times 10^6 \times \frac{\text{Lb.}}{\text{in.}^2}}$$

$$= \frac{800 \times 8 \times 20\ \ \text{in.}^5}{16 \times 12 \times 10^6\ (\text{mm.})^4}$$

$$= \frac{800 \times 8 \times 20 \times (25{\cdot}4)^4}{16 \times 12 \times 10^6}\text{ in.} = 0{\cdot}21\text{ in.}$$

The deflection being obtained in inches is a guarantee that no factor having dimensions has been omitted, and although nothing has been saved by employing mixed units in this case that is not so in every example.

There is one type of problem which the writer has found by experience presents very great difficulties to students employing other systems than the Stroud, but which becomes very easy when using that system. It is the change of units in an empirical equation. The size of the unit and the number naturally are in inverse ratio and the difficulties arise from that fact. Consider the empirical equation of the flow of water through a 90-deg. notch. It is F = 0·305 H$^{5/2}$, in which H is the head in inches above the bottom of the notch and F is the flow in cubic feet per minute. Convert this equation first of all into a scientific one in which the symbols contain their own units. It is

$$\frac{\mathrm{F}}{\mathrm{H}^{5/2}} = 0{\cdot}305\ \frac{\text{ft.}^3}{\text{min.}\ \ \text{in.}^{5/2}}$$

If in this equation H be substituted in inches it is

* Contribution to a Joint Discussion of Sections G. and L. of the British Association at Liverpool, September 18, 1923.

evident that F is in ft.^{3}/min., but H may be substituted in any unit and the same result will be obtained provided the unit be inserted with the number in the equation.

If now the value of the constant be required when H is in centimetres and F in cubic metres per hour, we proceed mechanically, thus

$$\frac{F}{H^{5/2}} = 0{\cdot}305\ \frac{\text{ft.}^3}{\text{min.}}\ \frac{}{\text{in.}^{5/2}} = 0{\cdot}305\ \frac{\text{metres}^3}{(3{\cdot}28)^3} \times \frac{60}{\text{hour}}$$

$$\times \frac{1}{(2{\cdot}54\ \text{cm.})^{5/2}}$$

$$= \frac{0{\cdot}305 \times 60}{(3{\cdot}28)^3 \times (2{\cdot}54)^{5/2}}\ \frac{\text{metres}^3}{\text{hour} \times \text{cm.}^{5/2}}$$

$$= 0{\cdot}0504\ \frac{\text{metres}^3}{\text{hour} \times \text{cm.}^{5/2}}$$

The writer has been careful so far to give only his personal experience of thirty years' use of the Stroud system confined as that has been to students of university standing. There may be room for difference of opinion as to whether such a system can be taught to school boys. The writer is of opinion that such a change is desirable, and would go even further and introduce the system of labelling, which is an important feature of the Stroud system, in the teaching of arithmetic. In problems in so-called proportion, many of which are really problems in rates, considerable mental effort is saved and accuracy increased if the boy and girl can write down the rate with the labels attached.

Example.—If 10 men plough 100 acres in 20 days, how many days will 6 men take to plough 60 acres?

The rate of working

$$= \frac{100\ \text{acres}}{10\ \text{men} \times 20\ \text{days}}$$

$$= \frac{1}{2}\ \frac{\text{acres}}{\text{men} \times \text{days}}$$

or alternatively,

$$\frac{2\ \text{men} \times \text{days}}{\text{acre}}.$$

In the answer time is wanted, and there is only one method of substituting the new data to leave time alone in the answer.

$$\text{Time} = \frac{2\ \text{men} \times \text{days}}{\text{acre}} \times 60\ \frac{\text{acres}}{6\ \text{men}}$$

$$= 20\ \text{days}.$$

If the boy or girl can write down the rate correctly the rest of the problem becomes mechanical.

The introduction of the system of labelling at this early stage would form an early introduction to one of the features of the Stroud system which contribute in large measure to its success, and would at the same time simplify the teaching of arithmetic.

In conclusion the writer hopes that he has been able to show that the Stroud system is more logical than any other in that all other systems become special cases, and also that Professor Stroud's artifices are valuable aids to accuracy in the laboratory and in the engineering workshop.

DEVELOPMENTS IN WIRELESS TELEGRAPHY.*

Recent Developments in the Application of Wireless Telegraphy to Shipping.

By Commander J. A. SLEE, C.B.E., R.N. (ret.).

High-speed Apparatus.—The very heavy traffic handled by the largest of the transatlantic liners has brought about requirements for automatic transmission and reception, in order that the large number of messages with which they have to deal may be handled without monopolising the attention of coast stations for an unwarrantably long period. The method adopted for obtaining high speed transmission in ships is as follows:

The aerial circuit is magnetically coupled to a closed circuit which is kept in a state of constant oscillation by the transmitting valve. The coupling between the closed and open circuits is arranged in two equal parts which are opposed to one another. The act of signalling consists in short-circuiting one half of this coupling and so allowing the transfer of energy from the closed to the aerial circuit to take place through the remaining unbalanced portion.

In order to keep the load on the transmitting valve constant an artificial resistance is inserted in the closed circuit, which is short circuited at the same moment that the compensating half of the coupling coil is short circuited. This allows of fairly high speed transmission without the slightest trouble from sparking at the key contacts. Speeds from 60 to 90 words a minute are worked as the circumstances of the moment may dictate.

The source of supply is the standard nominal 1½ kw. valve transmitting panel, the supply to the anode of the transmitting valve being approximately 1·2 kw. The aerial current for a prolonged dash is about 7 amperes and the effective range of transmission at 90 words a minute is about 700 miles. The high speed keying is carried out by means of a Wheatstone or Creed transmitter working from a perforated tape.

The high-speed receiving apparatus consists first of all of the usual loosely coupled circuits tuned to the frequency of the wave which it is desired to read, the high frequency current being amplified by six high frequency valves working in a transformer-coupled amplifier of the well known "55" type. The amplified current is acted upon by a local oscillator, the tuning of which is arranged to be very accurate, a tangent screw being fitted to the adjustable condenser in order that the beat frequency may be fixed with great accuracy. After rectification the rectified current now at the beat frequency is passed through a four-stage low frequency tuning circuit. This consists of a four valve low frequency amplifier, each of the grid circuits being tuned to the pre-determined beat frequency, the anode circuit of one valve being loosely coupled to the grid circuit of the next.

Such a device gives very considerable magnification to sounds of the pre-determined frequency, but the magnification is less than one to one for any signals differing by but a very small amount from the frequency of the filter. Hence the necessity for a tangent screw to give exceedingly fine adjustment of the local oscillator frequency, which of course determines the pitch of the beat note.

After passing through the filter the signals are again rectified and applied to the grid of the valve which operates the recording device. The anode current from this last valve is used to actuate the recorder, the current being to all intents and purposes a direct current whose strength varies between practically zero and about 5 milliamps. Extremely satisfactory results have been obtained at sea from undulators of the type introduced by Dr. MacLachlan. These are very reliable in operation and completely proof against vibration and movement of the ship.

Receiving speeds up to about 100 words per minute can be obtained by the means as described above when signals are strong.

The automatic recorder is exceedingly useful as, in addition to its use for the reception of high speed signals, it can also be switched on and allowed to record ordinary hand speed messages, such as press messages, while the ship's operators can be employed in reading messages on other wave lengths independently of the recorder. It should be realised that double reception, that is to say, reception of signals on two different wave lengths at the same time in the same ship, s now a common practice in these very large vessels. (See Figs. 1 and 2.)

Note Filters.—The recent rapid increase in the number of powerful wireless stations has made the reading of press messages in ships at sea exceedingly difficult, because there are many parts of the ocean where the received high frequency currents from the station whose messages it is desired to read are very much weaker than the high frequency currents received from other stations of very slightly different wave length. This means that two or more messages are audible in the telephones at the same time, and although they may all have different beat notes yet it is exceedingly difficult for the human ear to pick out the weaker sound which is required from among several louder sounds.

To overcome this difficulty, two-stage note filters, similar in principle to the four-stage note filters described above, are now in use. Although of course the tuning obtained is not so sharp as is the case with the four-stage note filters, yet it has been found sufficient and very greatly to simplify the problem of reading press messages in ships on the high seas.

It should be noted that these note filters are only of practical use for reading continuous wave messages in which the pitch of the note received can be varied at will by an alteration of the frequency of the local oscillations, and thus adjusted so that the desired signal is received at the beat note corresponding to the selective frequency of the filter. Filters are of no practical service for spark telegraphy because in this case the pitch of the note of the received signals depends upon the transmitter only and is not under the control of the receiving telegraphist.

Wireless Beam.—A great step in the adaptation of wireless telegraphy as an assistance to navigation has been taken in the production of what are known as revolving beam stations. These stations transmit a wireless signal on an exceedingly short wave (about 6 metres) in the form of a very fairly concentrated beam, and the whole apparatus of the transmitter can be rotated bodily on a turn table (Fig. 3).

Special receivers suitable for this exceedingly short wave telegraphy can be fitted and by their aid the signals sent out by the revolving beam transmitter can be received. This altogether abnormal form of telegraphy is entirely free from interference from other signals, and in consequence there is no difficulty in reading simple signals such as the single letters transmitted by

Fig. 1. HIGH SPEED TRANSMITTER.

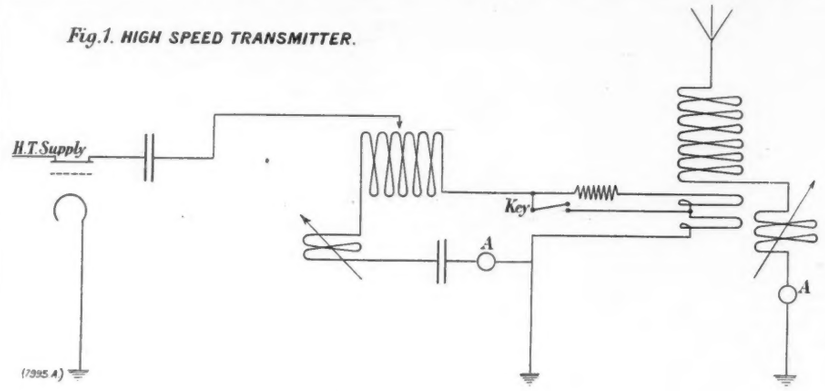
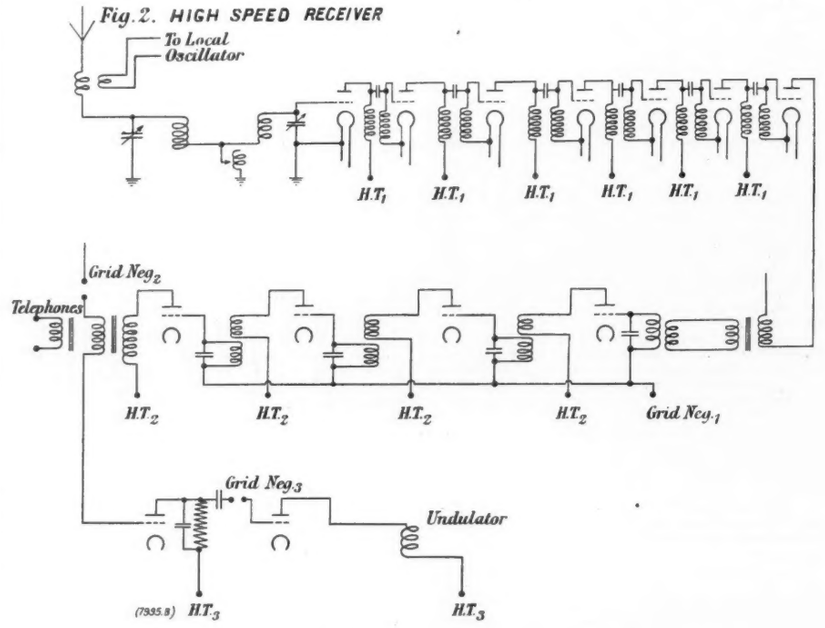


Fig. 2. HIGH SPEED RECEIVER



* A paper read before Section G of the British Association at Liverpool, September 17, 1923.

its aid. For this reason it is not necessary to make use of the services of a skilled telegraphist, and navigating officers have no difficulty in learning to use the receiver for themselves.

The arrangements of the beam transmitter are such that signals will fall to about half their maximum strength about 10 deg. each side of the axis of the beam, falling away to practically zero a further 10 deg. each side of the axis. The method of signalling bearings by means of the beam is as follows:

As the projector is rotated a contact finger passes over studs on the turn table, which are arranged so as to produce a different letter, selected from the longer Morse letters, at each two points of the compass. A ship at the normal working range of the beam would thus hear either two of these long letters fairly loudly, in which case the bearing would be between them, or she would hear one long letter faintly, then one loudly, and a third faintly. This gives a rough indication of the bearing, but in order to allow of the bearings being read with a degree of accuracy sufficient for navigational purposes, the arcs between the long letters are split up by three equally spaced short letters, each of which of course will represent a half point of the compass. The letters in use are a T (one long) at the intervening points of the compass and an I (two shorts) at the intervening half points of the compass. As the beam passes over a ship the navigator would hear something of this kind—TILITIQITI.

With the receiving instrument a disc is provided marked in half points of the compass and fitted with two pegs

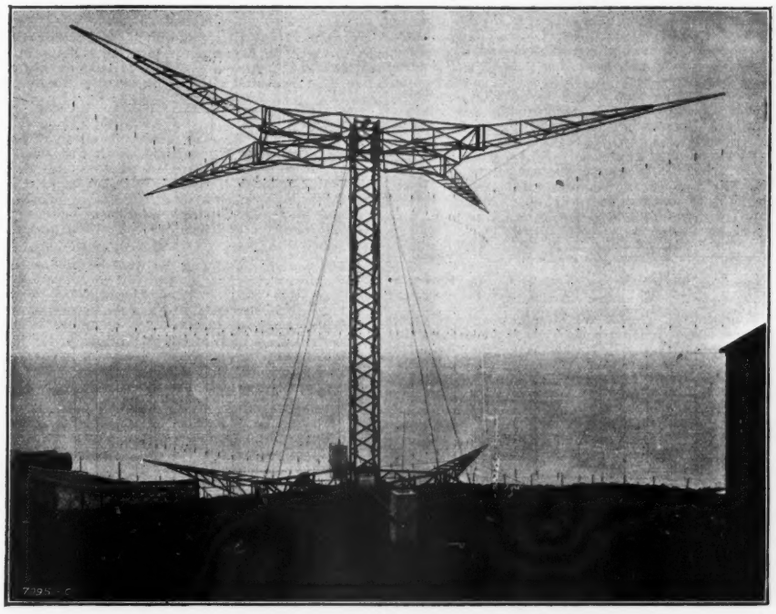


FIG. 3.

which the observer can stick into the disc at the first and last sound which he hears, and he can then rest assured that the bearings will be midway between the points indicated by the two pegs. This gives an accuracy of bearing of a quarter of a point.

At the time of speaking one such station exists at Inchkeith Island and a second is being erected near the South Foreland lighthouse. The whole subject is still in its infancy but it is felt that the use of this great boon to navigators will extend rapidly in the near future.

At present the range at which bearings can be obtained with accuracy and certainty is about 10 miles, and it has been shown that although the range of the beam may be reduced by the presence of intervening obstacles, yet there is no action tending to distort the path of the beam, and therefore this method of giving directions is not susceptible to any electrical error. Also it should be noted that this method of signalling the bearing is independent of the rate of revolution of the projector.

The absorption experienced by such very short waves is very great, so much so that it is not possible for a receiver fixed on the distant side of a ship to perceive the signals, and therefore in practice two receivers have to be fitted, one at each end of the bridge, in order to make certain that one at least of them will be operative under all conditions.

The receiver itself consists of two brass rods about a yard long fixed vertically and end to end, projecting from a small case which contains the tuning appliances. An amplifier and telephones are fitted in the chart house of the vessel, and when the navigator believes himself to be within range of a revolving beam projector he switches on the amplifier and listens.

Or course there is no difficulty in joining up a loud speaker, in which case it would give audible warning should the vessel come within range of the beam.

It is, of course, necessary to standardise beam transmitters, especially as to whether their bearings shall be true bearings or magnetic bearings, and also to standardise the use of the "long" Morse letters to indicate the alternate points of the compass. As the tuning is exceedingly sharp it is also necessary that it shall be permanent, and therefore it is necessary that the wave length of the beam transmitters should also be standardised.

If two beam transmitters are in operation in the same neighbourhood it will be necessary to make some kind of distinction between them, and this can best be done by making use of various combinations of short letters. Thus one beam might use I T I, another I S I, another I N I, another I A I, and any of the large number of possible combinations.

Direction Finding.—It is very gratifying to note the steady improvement in the accuracy of the long range direction finders, as worked in seagoing ships. These instruments, as is well known, are intended to obtain a bearing of any vessel or coast station, making use of their ordinary wireless transmitter. Their available range is nominally 100 miles, which is about the greatest distance of real value to navigation, although accurate bearings are often obtained at three times this distance.

On account of the considerable amount of interference which exists on the wave lengths in common use among ships, the services of a really skilled telegraphist are required to operate the direction finder, and it is also highly desirable that it should be in charge of thoroughly trained men who can at once detect the fact of its going out of order and, within reasonable limits, identify and repair any defects.

Now that the causes of error of direction finders themselves are understood and can be eliminated or compensated for, and consequently reliance can be placed upon the performance of the instrument, it has become possible to commence the search for causes external to the instrument itself which may lead to erroneous bearings. It has been well known for a long time that if the line of bearing between the receiving ship and the transmitting shore station cuts the coast line at an acute angle errors will be introduced, and by careful examination of the charts and an examination of the accuracy or otherwise of direction-finder bearings from ships in which the average accuracy has proved itself to be very high, it has begun to be possible to mark out certain arcs in which direction-finder bearings of some shore stations are liable to error. This is a complicated undertaking now only in its infancy, but it is hoped that with the co-operation of the navigating officers of ships fitted with direction finders it will be possible to add very greatly to the accuracy of the knowledge which we now possess on the subject and to the number of stations about which it is possible to lay down definitely their arcs of good and bad bearings.

It must be realised that the direction finder if mounted in a ship can only measure angles relative to the keel line of the vessel, and that before such bearings can be used for navigational purposes they must be translated into true bearings (that is to say, bearings relative to the meridian) by the navigators.

Therefore the successful use of the direction finder is almost as much dependent upon the navigating staff as upon the telegraphist, and the very successful results which are now being obtained in vessels fitted with direction finders could not possibly have been reached without the hearty co-operation which exists between the navigational staff and the wireless staff.

Telephony.—Advances in wireless telegraphy have allowed telephony to be carried out in accordance with the method which is generally called "duplex," that is to say, that it allows of transmission and reception at the same time in a fashion exactly similar to the use of the ordinary desk telephone.

There are two distinct methods whereby this can be achieved. According to one of them each station transmits on one wave and receives upon another, which differ from one another so widely that the transmitter can be arranged to have little or no effect upon the receiving instruments of the same station. This method is simple, but it is very prone both to cause and to suffer from interference, due to the fact that two very widely differing waves are employed for the purpose. A second method is to make use of two waves near to one another, so chosen that the beat frequency will be above human hearing. This method possesses many advantages, the only difficulty being that of making use of more than a very moderate amount of power.

Experiments are in hand with a view to linking up vessels within a moderate distance of their terminal ports (say 50 miles) with the local Post Office Telephone Exchange system.

There is no particular difficulty in obtaining and maintaining good telephonic speech with the wireless telephone station on land, the real complexity of the problem arising when the land telephone station has to be operated by subscribers at greatly varying distances from the exchange, as it is necessary that speech should reach the wireless telephone transmitter at some fairly definite intensity in order that distortion on the one hand and faintness on the other may be avoided. The same remark applies to the intensity of speech which must be handed over from the wireless telephone receiver to the land line telephone system.

In order that the matter may be placed on an economic basis it is necessary that the land telephone apparatus should work unwatched, and the experiments now in hand are directed mainly at overcoming the troubles outlined in the above paragraphs.

At present no very ambitious scheme has been undertaken, as it is felt that the first objective is to obtain communication between a vessel say 50 miles at sea and a limited number of special subscribers at her home port. More ambitious schemes for extending the use of telephony between ships and the shore can be undertaken when the preliminary stages outlined above have been formally established.

STRESSES IN BRIDGES.

By J. S. WILSON, A.C.G.I., Assoc.M.Inst.C.E., and Professor B. P. HAIGH, D.Sc., M.Inst.C.E.

IN recent years the stresses in iron and steel bridge members have been investigated in detail and have been demonstrated by experiment and mathematical analysis to be of a complex nature. The investigations have an important bearing on the choice of maximum or nominal stresses adopted in bridge design. The question of allowable stress and its complement, loading, in relation to railway bridges has during recent years received a great deal of attention in America, India and this country. Here and in India elaborate experimental researches are still in progress. These investigations were rendered necessary by the gradual increase in locomotive weights and the necessity of deciding on the renewal of some of the older bridges.

In this country we have the oldest railway bridges in existence, many of which have successfully carried all locomotives and trains without restriction for upwards of sixty years, and as the stresses in these bridges have an important bearing on the subject, the system followed in their design is of interest.

Method of Design by Coefficient.—It is important to note that the strength of these early bridges and girders was not estimated in relation to the stresses in them till 1859. Before that time the working strength was always referred to the breaking strength of the girder which was calculated from the dimensions with the help of a coefficient determined experimentally for the different types of girder section. Thus at about the date mentioned, Sir William Fairbairn wrote:—"After the completion of the Conway and Britannia tubular bridges, and during the early stages of wrought-iron bridge constructions, the engineers of this country and the Board of Trade had adhered to the principle that every bridge composed of wrought iron, whether designed upon the plate, lattice, or tubular principle, should have a resistance, tending to break the bridge, (*sic*) of six times the rolling load, exclusive of its own weight."†

"Owing to the success of these undertakings (the Britannia and Conway tubular bridges) there was a general demand for wrought iron bridges in every direction, and numbers were made without any regard to first principles, so clearly and satisfactorily shown in the early experiments. The result of this was a number of weak bridges, many of them so disproportioned in the distribution of material as to be almost at the point of rupture with little more than double the permanent load.

"The defects and breakdowns which followed the first successful application of wrought iron to bridge-building led to doubts and fears on the part of engineers; and many of them contended for eight and even ten times the heaviest load as the safe margin of strength. Others, and amongst them the late Mr. Brunel, fixed a lower standard; and, I believe, that gentleman was prepared in practice to work up to one-third or two-fifths of the

* Contribution to the Report of the Committee of Section G of the British Association on Complex Stress; Liverpool, September 18, 1923.

† Researches on the Application of Iron to Buildings. W. Fairbairn.

ultimate strength of the weight that would break the bridge. Ultimately it was decided by the authorities of the Board of Trade, but from what data I am not informed, that no wrought-iron bridge should with the heaviest load exceed a strain of 5 tons per square inch."*

The coefficient to give the breaking strength was used in the simple formula :—

$$W = \frac{a\ d\ c}{l}$$

W = Breaking load in tons applied at centre of girder.
a = Sectional area of flange in tension.
d = Overall depth in inches.
l = Length in inches between supports.
c = Coefficient.

Applied to cast-iron girders for instance, in which the tension flange had an area six times as great as the compression flange, the coefficient was 26. For wrought iron tubular or box girders it was 80, for plate web girders 74 and lattice girders 67.

These coefficients were based on experiments made on large scale models in which the most satisfactory distribution of sectional area for tension and compression was determined and coefficients were applied to full size girders with the metal in the flanges similarly distributed. This system not being based on stress did not assume a straight line distribution of stress, but with a coefficient based on a breaking strength, when parts would be stressed beyond the yield point, it must of necessity indirectly assume other than a straight line distribution. Among the many famous iron bridges built on this coefficient principle are the Britannia and Conway tubular bridges ($c = 80$), and the Tay bridge (Highland Railway) ($c = 74$).

The introduction of the stress method revolutionised the system of design and the distribution of stress had to be considered. The fixing of a stress of 5 tons per square inch as the maximum without any details as to its application to different parts led to great uncertainty, and also to further most important investigations. In applying the coefficient method the reduction of area by rivets in the tension flange had been disregarded as it was also disregarded when determining the coefficients experimentally. The unexpected necessity of measuring the strength of a girder in a new unit with which engineers were not familiar naturally led to enquiries as to how the new standard compared with what had been proved by actual practice to be satisfactory. Fairbairn having at that date (1859) just completed the Spey bridge, and the Board of Trade taking exception to it on account of the stress being above 5 tons per square inch, it was decided to make a test on a riveted girder roughly of the proportions of the Spey bridge. To quote Fairbairn, " . . . the Board of Trade threatened to stop the traffic which had been at work some months over the bridge. To make everything smooth, it was ultimately arranged that the bridge should be strengthened up to the standard adopted by the Board of Trade, on condition that the Treasury should grant 150*l.* to defray the expense of experiments to ascertain the durability, and the measure of strength to be allowed, of wrought-iron bridges, subjected to changes, shocks, and vibrations of a continued and variable load."†

This fatigue test carried out on a riveted girder 20 ft. long is unique.

Dr. W. C. Unwin, F.R.S., who assisted Fairbairn in making this remarkable experiment which continued for two years, remembers the circumstances well, and has kindly helped to supply information. The load was applied at the centre of the girder at the rate of about eight changes per minute, and the shock was sufficient to make the girder vibrate vertically for some seconds at every application.

The details of the experiment are rather scattered among Fairbairn's books and reports. Some particulars with additional figures are given in the appendix hereto.

The experiment proved that the metal of the girder would withstand over three million repetitions of a stress, accompanied by shock, of 6·25 tons per square inch on the net area, and we know that if three million repetitions fail to rupture, the stress can be little, if any, greater than that which may be applied an unlimited number of times.

Notwithstanding the result of the experiment, the 5-ton limit remained unaltered, and this preliminary reference to the introduction of the stress system of design and the fixing of the five-ton limit, is given in order to emphasise the fact that the limiting stress fixed was not based on any very thorough investigation of the stresses in the successful or unsuccessful iron bridges built before the introduction of the new limit. Among the bridges still in daily use therefore we have, as stated in the extract from Fairbairn above, bridges designed intentionally with various factors of safety. The stress limit having been fixed, however, any disregard of it led to delay in the opening of new railway extensions,‡ consequently all new railway bridges *had* to be built to that limit. Although stipulated as the maximum, stresses in those days were only calculated approximately, and the five tons per square inch can only be regarded as a nominal stress.

STRESSES CONSIDERED IN DESIGN.

Changes of stress in bridge members can be determined with considerable accuracy by strain meters, as has been done in the recent investigations. An increase of stress measured in this way* while an engine or train passes over at speed would generally be greater than that measured with the engine standing. Both these measured stresses would be different from the figure arrived at by calculation in the usual way even for the exact axle loads of the engine and train. Denoting the several stresses by symbols we have :—

f_v = Stress increase measured under travelling load.
f_s = Stress increase measured under standing load.
f_c = Stress increase calculated for standing load.
f_d = Stress due to dead load of structure.

The difference between f_v and f_s may be due to speed combined with its concomitant vibrations of bridge and load. That between f_s and f_c to the method of calculation not being sufficiently exact as to stress distribution or inclusion of secondary stresses.

The difference between f_v and f_s, though not actually measured in the early days, was nevertheless realised from the beginning, and some system was required for the graduation of the nominal stresses so as to enable bridge members to withstand the expected increase, without damage. The next development was the preparation by several engineers and various railway authorities of designing specifications which, in addition to fixing the stresses, gave instructions regarding details of design and formulæ for compression members. Two distinct methods have been followed in drawing up these specifications.

GRADUATED STRESS SPECIFICATIONS.

In one are given a series of stresses, carefully graduated according to the length and character of the bridge member having regard to the relation of $f_d + f_c$ to f_d and the expected effect of fatigue combined with the relative values of f_v and f_s. The late Sir Benjamin Baker's well known specification for steel main line bridges is of this type and has been extensively used in the design of a very large number of bridges and other structures in this country and abroad. This specification was prepared in 1892 and published later.†

In another form of graduated stress specification, the graduation is done according to the range of stress. The following are examples of formulae which have been used by two British railways :—

Maximum permissible stress in member or part,

$$= 4{\cdot}66\left(1 \pm \frac{\text{Minimum load or B.M.}}{2 \times \text{Maximum load or B.M.}}\right) \text{ tons per sq. in.}$$

$$= 4{\cdot}0 \div \left(1 - \frac{\text{Minimum load or B.M.}}{2 \times \text{Maximum load or B.M.}}\right) \text{ tons per sq. in.}$$

These graduated stresses are obviously extensions of the simple stress limiting rule originally made by the Board of Trade. The type of specification may be called the graduated stress specification. It is perfectly definite and easy to apply and has many advantages over the alternative form.

Standard Stress and Impact Specifications.—The second type may be called the single or standard stress specification. In it the load or moment to be borne by any particular member is increased by a factor so that that larger load represents the increased or more damaging effect of the actual load travelling at speed and of any other influence. The particular member is then designed to carry this increased load on the basis of a standard maximum stress. This type of specification is of American origin and there are many variations of it. One of the first formulae for getting this increase of load to be added, appeared in a Specification prepared by Mr. Schneider for the Pencoyd Company and is now well known as the Pencoyd formula.*

The additional allowance termed "impact" is based on the loaded length of the girder when the greatest load or bending moment is brought to bear on the member considered. The addition to the load thus made, taken in conjunction with the standard stress allowed, covers the necessary provision for fatigue and vibration, &c.

This formula and slight modifications of it have been very extensively adopted.†

Recent Investigations.—The question of bridge renewal in America led to the elaborate investigations made by the American Railway Engineering Association, from 1907 to 1909, described in their Bulletins of 1910. In addition to the question of loading, the important subject of impact was investigated and a modified co fficient $\frac{30{,}000}{30{,}000 + L^2}$ was adopted as preferable to that in the Pencoyd formula.

The investigations of the Indian Railway Bridge Committee, carried out for the Government of India, were started in 1917 and are still in progress.‡

The work has been directed principally to the consideration of the "impact" question and the possible substitution of a new formula for the Pencoyd one which was adopted for Indian railway bridges in 1903.

The experimental work in this country has been done by the Ministry of Transport, and investigations made in 1920 are given in the Report of 1921.§

In that report the impact coefficient suggested is

$$\frac{120}{90 + L}.$$

In connection with each of these investigations, a large number of experiments have been made in which strains taken on various lengths, and deflections of girders have been measured with the object of getting values of

$$\frac{f_v - f_s}{f_s}.$$

In some cases only the maximum strain during the passage of the load is measured as with the La Touche gauge, and in others a complete photographic record of the strains against a time base is made, as with the Fereday-Palmer instrument. The value of the ratio obviously depends on a large number of factors relating to the locomotive and train as well as the bridge itself, such as :—

The moving load and its distribution among the axles.
Speed.
The unbalanced revolving and reciprocating parts.
Stiffness of springs.
Longitudinal and lateral oscillations of the loads.
Weight and various characteristics of stiffness, period of vibration, &c., of the whole bridge as well as of any particular part under investigation.

The analysis of the experimental records is difficult owing to the large number of variable factors which affect the results. In some cases, to assist in the analysis of the strain-time records, the positions along the girders at which the effects of unbalanced weights would take effect have been recorded. These positions can be controlled within limits but equally powerful influences such as those of the pitching and rolling and side lurching of a locomotive travelling at speed are so far uncontrollable.‖

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* Philosophical Transactions, 1864, p. 316. "Experiments to Determine the effect of Impact, Vibratory Action and long-continued Changes of Load on Wrought-Iron Girders," by W. Fairbairn, LL.D., F.R.S.

† Researches on the Application of Iron to Buildings. W. Fairbairn.

‡ See reference to Torksey bridge at Hull meeting, ENGINEERING, September 15, 1922, p. 350.

* A stress deduced thus from strain must of necessity be the increase due to the live load. The dead load stress cannot be measured, as the girder cannot be relieved of the dead load.

† The graduated stresses are as follows :—

Tensile Stresses.

For main girders, cross girders, and rail bearers of plate construction :—

	Tons per Square Inch.
Under 20 ft. span	4½
20 ft. and under 25 ft.	4⅝
25 ft. and under 30 ft.	5
30 ft. and under 50 ft.	5⅛
50 ft. and above	5½
For truss or lattice girders—	
80 ft. and under 160 ft. span—	
Bottom chords	5⅛
Diagonals	4½ to 5½
160 ft. and under 200 ft. span—	
Bottom chords	5⅜
Diagonals	4½ to 5⅜
200 ft. to 400 ft. span—	
Bottom chords	6 to 7
Diagonals	4½ to 7
For wind bracing all spans	8½
For floor suspenders, all spans ...	2½

NOTE.—The 4½ tons stress on the diagonals will apply to those at the central portion of the span and to the counterbracing at the same point. The higher stresses will apply to those at the end portions of the span where the variations of stress are not so great. Intermediate diagonals will be subject to stresses lying between the two limits. The object in all cases of the varying working stresses is to guard against the relatively destructive action of suddenly applied loads on lightly loaded girders or members of girders, having reference both to the effects of impact and to the inferior ultimate resistance of material subject to considerable and frequent variations in stress. Special regard must be had to these conditions in the general design of the bridgework, and in the form and proportion of gussets and other minor details.

* Extract from the section book of the Pencoyd Company.

"*Effect of Impact.*—In proportioning the members of the structures, the effects of impact and vibration shall be considered and added to the maximum strains resulting from the above mentioned engine and train loads. The effect of impact is to be determined by the following formula :—

$$I = S\left(\frac{300}{L + 300}\right)$$

I = Impact to be added to the live-load strain.
S = Calculated maximum live-load strain.

where L = length of loaded distance in feet which produces the maximum strain in member.

Permissible Tensile Strains.—All parts of the structure shall be so proportioned that the sum of the maximum loads, together with the impact, shall not cause the tensile strain to exceed.

On soft steel, 15,000 lb. per square inch.
On medium steel, 17,000 lb. per square inch.

The same limiting unit strains shall also be used for members strained by wind pressure, centrifugal force, or momentum of train."

† An interesting comparative table giving the flange areas of, rail bearers, cross girders and main girders required to satisfy five representative specifications applied to a particular bridge has been prepared by Mr. Conrad Gribble, Proc.Inst.C.E., vol. cc, p. 238.

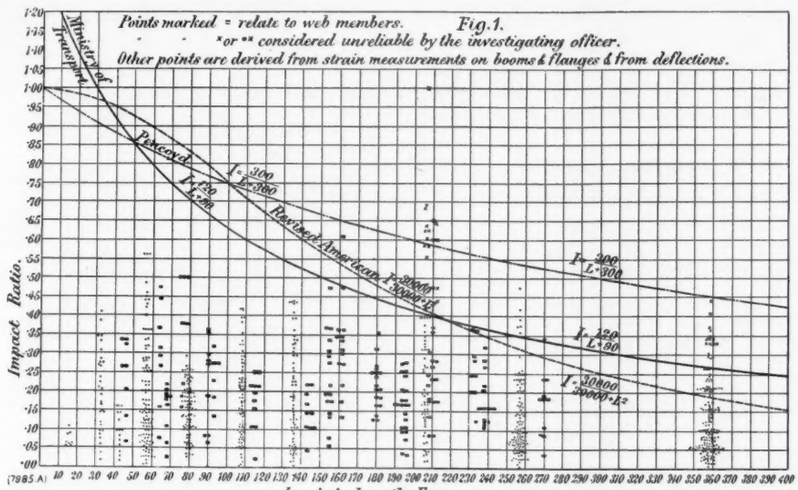
‡ Indian Railway Bridge Committee, 1st report, 1917, Technical Paper 187 ; 2nd Report, 1918, Technical Paper 198 ; 3rd Report, 1919, Technical Paper 211 ; 4th Report, vol. i, 1920, Technical paper 224 ; vol. ii, 1920, Technical Paper 225 ; 5th Report, 1921, Technical Paper 228. See also Technical Papers, 194 and 199.

§ Ministry of Transport. "Tests on Railway Bridges in respect of Impact Effect, 1921.

‖ An instance is given by Baker in "Long Span Bridges" of the destructive effect of these influences. The platform and shallow cross girders of a bridge were completely destroyed in four years by locomotives of short wheel base and long overhang, although the calculated stresses in the ironwork did not exceed 4 tons per square inch.

Also the single very high impact ratio of 159 per cent.

A very large number of measurements are available, 362 made by the Ministry of Transport, and about three thousand by the Indian Railway Bridge Committee in addition to a large number of American records. Deflections and strains can be measured accurately enough under stationary and slowly moving loads, but when the movement is rapid, vibrations of the bridge and its parts combined with the inertia of the instrument have resulted in many of the records being considered of doubtful accuracy. The measurements made by the Ministry of Transport and 1,500 of those made by the Indian Bridge Committee were taken with the Fereday-Palmer photo recording instrument, a carefully designed and accurately made apparatus the records of which are considered accurate. All the most accurately


Points marked = relate to web members.
* or ** considered unreliable by the investigating officer.
Other points are derived from strain measurements on booms & flanges & from deflections.
Fig. 1.
Ministry of Transport
Percent.
I = 300 / L+300
I = 120 / L+80
Revised American I = 30000 / 30000+L²
I = 200 / L+300
I = 120 / L+80
I = 30000 / 30000+L²
Impact Ratio.
Loaded Length. Feet

measured ratios of the Indian experiments are plotted in Fig. 1* in which the graphs of the various impact formulæ are also drawn. The points marked * are considered unreliable by the investigating officers because the "measured static stress on which they are based are extremely low." It will be seen that for each particular loaded length up to 200 ft. the numerous ratios are distributed comparatively evenly over a range of from 0 to 45 per cent. The same ratios plotted against speed fall into no recognisable order as the following figures show. For instance, the ratio for 18 miles per hour is higher than that for 45·4 miles per hour, and all that can be deduced is that generally they rise with increase of speed.

Speed m.p.h.	Impact Ratio.	Speed m.p.h.	Impact Ratio.	Speed m.p.h.	Impact Ratio.
	Per cent.		Per cent.		Per cent.
7·8	7·5	30·2	36·0	39·7	28·0
12·0	3·5	31·7	22·5	40·8	36·5
16·5	10·2	32·3	32·0	43·8	20·0
18·0	36·0	34·3	25·0	44·3	56·0
18·5	32·0	36·7	22·0	45·4	33·5
24·7	43·5	37·0	45·0	46·3	46·0
25·7	17·5	37·8	20·0	49·6	56·5
27·2	16·0	39·0	31·0	55·6	46·0

The widely varying nature of these ratio measurements is obviously due to vibrations set up by the uncontrolled causes, indeed, ratios that would plot along a defined graph could hardly be expected. Exhaustive and very skilful attempts to analyse various strain-time records have been made by Messrs. C. W. Lloyd-Jones and H. S. Sales, of the Indian Bridge Committee, but even with the assistance of freely made assumptions the results are disappointing. The dominating causes in producing vibration are the kinetic characteristics of the moving load combined with the vibration periods of the bridge and its various parts, together with the degree to which one synchronises with the other. This leads to the unavoidable conclusion, suggested by Mr. Lloyd-Jones, that to interpret records requires both the locomotive and bridge to be "calibrated" experimentally with respect to the above characteristics. With a calibrated bridge and calibrated locomotive a strain-time record taken with all variables under control could probably be analysed so as to determine the maximum ratio producible in members of that bridge by that locomotive.

In view of the above, it seems obvious that, in making attempts to arrive at the impact ratio by measuring strains, the same load might be run over a bridge, under identical conditions so far as could be controlled, very many times before the maximum value on a member might be registered.

obtained by the Ministry of Transport in their experiments was measured on one side of a shallow trough rail bearer, a case where lateral movement and the exact lateral position of the application of the load would have a marked effect on the stress.

* From the 5th Report, Indian Railway Bridge Committee.

The solving of the impact ratio problem will therefore necessitate a large amount of research, for with the variety of bridges and numerous types of more or less well-balanced locomotives, many combinations will have to be investigated.

Having attained such exact maximum ratios, however, the likelihood of their taking effect except at long intervals would have to be considered in fixing the standard stress to be adopted with them.

An alternative course to that suggested above would be to treat a number of the older bridges as full size experiments which have been under test for the last fifty or sixty years. Strain measurements under simple definite static loads would give the relation of actual stresses to those calculated in the usual manner and similar measurements under stationary loads equal to those which the bridges have carried successfully at speed, would provide nominal or basic stresses for guidance in design.

(To be continued.)

BRITISH CATALOGUES FOR CANADA.—His Majesty's Senior Trade Commissioner in Canada (Mr. R. W. Dalton) has informed the Department of Overseas Trade that there is a serious lack of British catalogues in the various Trade Commissioners' offices in Canada. He points out that without such catalogues it is often a difficult matter to advise firms in Canada as to possible British sources of supply, and that the necessity of referring enquiries to headquarters in London takes time, during which business that might otherwise have gone to British firms is lost to them. United Kingdom firms desirous of ensuring their names being given to suitable enquirers should forward copies of their catalogues to any, or all, of the following:—His Majesty's Senior Trade Commissioner in Canada, 285, Beaver Hall-hill, Montreal; His Majesty's Trade Commissioner, 24, Adelaide-street West, Toronto; His Majesty's Trade Commissioner, 210, Winch-building, Vancouver; or the Chief Clerk, Office of His Majesty's Trade Commissioner, 703, Union Bank-buildings, Winnipeg. It should be noted that Customs duty is levied on catalogues entering Canada, and firms desiring to send them by parcel post should prepay such duty. For this purpose stamps may be obtained from the office of the High Commissioner for Canada, Kinnaird House, Pall Mall East, London, S.W.1.

PAINTING OF OIL TANKS.—A large-scale test of the value of different coloured paints for the reduction of evaporation losses from oil tanks will be made by the Department of the Interior through the petroleum experiment station of the United States Bureau of Mines, Bartlesville, Okla. Oil refineries have been greatly interested in this problem. In the past, many oil operators, especially throughout the eastern and the middle western fields, have adopted white or light-coloured paints for storage tanks. Tests previously made indicated that evaporation from tanks painted white averages about 1 per cent. to 1½ per cent. less than from tanks painted red, and about 2½ per cent. less than from tanks painted black. Paints presenting a highly glossy surface are less absorptive to thermal rays than those representing a matte surface. Experiments were conducted wherein small tanks containing benzine were painted in various colours (gloss finish) and then subjected to the rays of a powerful arc light for 15 minutes. Tin-plating and aluminium paint gave the best results. However, neither of these finishes is practicable for outside work, as iron coated with tin corrodes rapidly, and aluminium paint soon loses its gloss and becomes flaky. The rise in temperature of the benzine in a tank painted black was 31·5 deg. F., or 140 per cent. greater than the rise in a tank painted white. Although results such as obtained by these laboratory experiments could not be expected in actual practice, they indicate a decided advantage to be gained by painting storage tanks white.

EFFECT OF LOW-TEMPERATURE ANNEALING ON SOME MECHANICAL PROPERTIES OF COLD-DRAWN STEELS.*

By S. H. REES, B.Sc. (Research Department, Woolwich.)

Cold-drawn Carbon Steels.—The materials used were a mild and a high carbon steel. The mild steel was in the form of ¾-in. diameter rod which had been cold-drawn from $\frac{13}{16}$ in. diameter—a reduction of area of 14·8 per cent. The high carbon steel was freshly drawn from a rod of crucible steel. The reduction of area obtained was about 8·1 per cent.—from ¾ in. to $\frac{23}{32}$ in. diameter.

Chemical Analysis.

	Mild Steel	High Carbon Steel.
	Per Cent.	Per Cent.
Carbon	0·04	0·85
Silicon	0·003	0·24
Manganese	0·25	0·48
Sulphur	0·044	0·029
Phosphorus	0·039	0·013
Nickel	trace	0·14
Chromium	0·085	0·026

Brinell Hardness.—The hardness was tested with a ball of 5 mm. diameter and a load of 750 kg.

	Mild Steel.	High Carbon Steel.
Before drawing	105	268
After drawing	178	293

Elastic Properties.—Tests in tension and compression were carried out on test-pieces of 2 in. acting length, using the Ewing extensometer reading to 1/125,000 in. The elastic limit recorded is the limit of proportionality, and the yield-point the load giving a permanent extension of 0·2 per cent.

Effect of Low-Temperature Annealing.—Similar tests were made on test pieces of 2 in. acting length from material which had been annealed for 1 hour at temperatures from 100 deg. to 700 deg. C. The results are shown graphically in Figs. 1, 2 and 5.

Cold-Drawn Stainless Steels.—The materials used were ¾-in. diameter rods of the commercial products "cold-drawn, ground and polished stainless iron" and "cold-drawn, ground, and polished stainless steel."

Chemical Analysis.

	Stainless Iron.	Stainless Steel.
	Per Cent.	Per Cent.
Carbon	0·12	0·40
Silicon	0·16	0·52
Manganese	0·13	0·24
Sulphur	0·047	0·04
Phosphorus	0·034	0·026
Nickel	0·25	0·06
Chromium	12·0	13·6

Elastic Properties.—Results of tensile tests made on test-pieces of 8 in. acting length with the Ewing extensometer gave:—

	Stainless Iron.	Stainless Steel.
Limit of proportionality, tons per square inch...	5	7
Load first giving permanent set, tons per square inch	6	7
Actual permanent set on 8 in. length at 10 tons per square inch ...	0·00020 in.	0·00014 in.

Hysteresis loops were obtained by loading and unloading, as indicated in Fig. 7. The increase in loop area with increasing permanent set was greater in the case of the steel than in the case of the iron. Continuous loading without measurement of permanent set was carried out on test-pieces of 2 in. acting length both in tension and compression with the smaller form of Ewing extensometer reading to 1/125,000 in.

Effect of Low-Temperature Annealing.—Similar tests were made on test-pieces of 2 in. acting length from material which had been annealed for 1 hour at temperatures from 100 deg. to 780 deg. C. Results are shown graphically in Figs. 3, 4 and 6. Successive hysteresis loops were determined on an 8-in. acting length of the "stainless steel," between 0 and 10, 0 and 15, 0 and 20, and 0 and 25 tons per square inch. The test-piece was then annealed 1 hour at temperatures increasing from 100 deg. to 425 deg. C by 25 deg. intervals and similar loops determined.

Range of stress, tons per sq. in. ..	0·10	0·15	0·20	0·25
Permanent set disappeared after annealing at (deg. C.)	100	125	125	175
Loop area became zero after annealing at	200	325	375	425

Typical loops obtained in these tests are reproduced in Fig. 8.

Summary.—(1) The effect of the cold-drawing without subsequent annealing is shown in the case of the mild and of the high carbon steel. A considerable increase in

* Abstract of a paper contributed to the meeting of the Iron and Steel Institute, Milan, September, 1923.

the value of the yield-tensile strength ratio has taken place, and also in the value of the yield point both in tension and compression.

The directional effect of the cold-drawing is marked in the case of the high carbon steel.

Fig. 1. LOAD-EXTENSION DIAGRAMS. MILD STEEL (0·04 PER CENT. C.) ANNEALED ONE HOUR AT TEMPERATURES SPECIFIED.

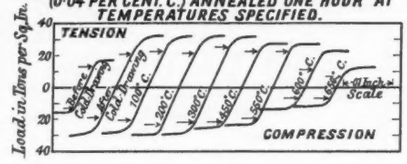


Fig. 2. LOAD-EXTENSION DIAGRAMS. HIGH CARBON STEEL (0·85 PER CENT. C.) ANNEALED ONE HOUR AT TEMPERATURES SPECIFIED.

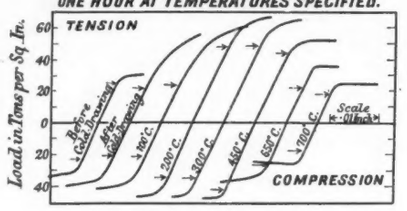


Fig. 3. LOAD-EXTENSION DIAGRAMS. "COLD-DRAWN STAINLESS IRON" ANNEALED ONE HOUR AT TEMPERATURES SPECIFIED.

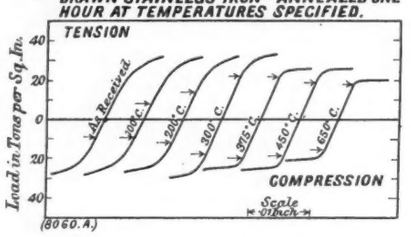
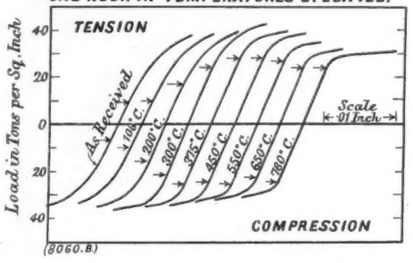


Fig. 4. LOAD-EXTENSION DIAGRAMS. "COLD-DRAWN STAINLESS STEEL" ANNEALED ONE HOUR AT TEMPERATURES SPECIFIED.



(2) The effect of low-temperature annealing on the maximum load and yield-point in the case of the mild steel and stainless iron is not appreciable, but they do not decrease in value until the material is annealed above 300 deg. C.

The stainless steel shows no increase in maximum load, but the yield-point is raised 4 tons in tension and 2 tons in compression—an increase of 10 per cent. and

	Mild Steel.	High Carbon Steel.
	Per Cent.	Per Cent.
Yield/tensile strength ratio before drawing...	67·4	50·0
Yield/tensile strength ratio after drawing ...	92·0	79·0
Increase in value of maximum load after drawing	39·6	10·9
Increase in value of yield-point after drawing. Tension	90·6	80·6
Increase in value of yield-point after drawing. Compression	90·6	19·4

7 per cent. respectively. The maximum load of the high carbon steel is increased by 4·2 tons, while the yield-point is raised by about 20 per cent. in both tension and compression. The yield-point, however, does not in compression reach the high figure attained in tension.

(3) The elastic limit in all cases is greatly improved by low-temperature annealing. The figures given below show the increased values obtained by annealing at 375 deg. C. in the case of the stainless steel and 300 deg. C. for the remaining three materials — the yield-point at these temperatures showing no appreciable fall. In the case of the stainless iron and high carbon steel a further increase occurs in the elastic limit tested in compression after annealing at 375 deg. and 450 deg. C. respectively, although the yield point in tension and the maximum load have fallen.

(4) The directional effect of the cold-work is probably a function of the original hardness of the steel and the amount of cold-working. It is very noticeable in the values obtained with the high carbon steel, but with the other steels it is not so apparent, although in no instance does the elastic limit in compression quite reach the figure attained in tension.

Fig. 5. MECHANICAL PROPERTIES OF HIGH CARBON STEEL (0·85 PER CENT. C.) ANNEALED ONE HOUR AT TEMPERATURES INDICATED.

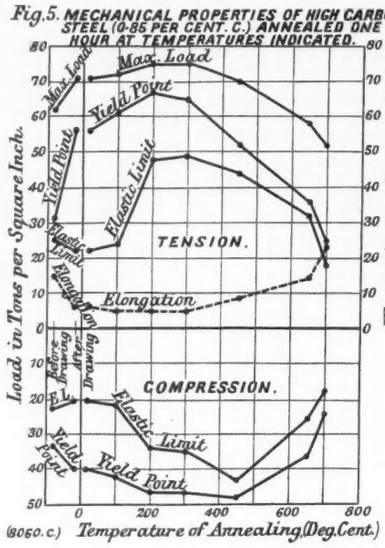
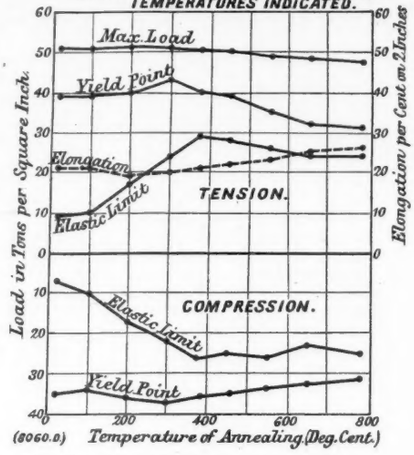


Fig. 6. MECHANICAL PROPERTIES OF "COLD DRAWN STAINLESS STEEL" ANNEALED ONE HOUR AT TEMPERATURES INDICATED.



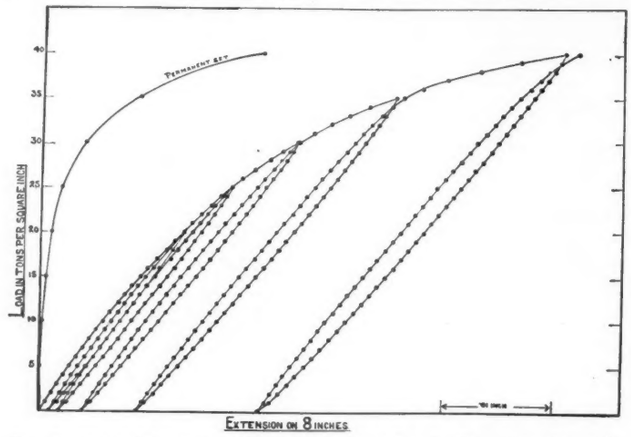


FIG. 7. LOAD-EXTENSION DIAGRAM. "COLD-DRAWN STAINLESS STEEL."

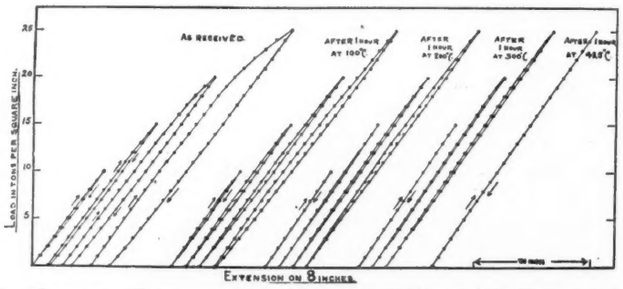

AS RECEIVED.
AFTER 1 HOUR AT 100°C.
AFTER 1 HOUR AT 200°C.
AFTER 1 HOUR AT 300°C.
AFTER 1 HOUR AT 415°C.
LOAD IN TONS PER SQUARE INCH
EXTENSION ON 8 INCHES

FIG. 8. HYSTERESIS LOOPS, BETWEEN 0–10, 0–15, 0–20 AND 0–25 TONS PER SQ. IN. TENSION, AFTER VARIOUS TREATMENTS. "COLD-DRAWN STAINLESS STEEL."

Material	Mild Steel.		High Carbon Steel.		Stainless Iron.		Stainless Steel.	
Tension or Compression	T.	C.	T.	C.	T.	C.	T.	C.
Elastic limit after cold-drawing, tons per square inch	20	19	22	21	7	9	9	7
Elastic limit after annealing at temperatures stated above, tons per square inch	25	22	49	35	22	18	29	26
Maximum figure for elastic limit after annealing, tons per square inch	25	24	49	43	22	20	29	26

(5) The elastic range is not a constant value in the materials investigated, and from the results given it would seem that the mechanical properties of all cold-worked steels are improved by a low-temperature treatment.

The author wishes to express his indebtedness to Dr. R. H. Greaves for his interest and valuable advice during the course of this work.

THE SHIPPING, ENGINEERING AND MACHINERY EXHIBITION AT OLYMPIA: ERRATUM.—In our account of the exhibits of the Yorkshire Copper Works, Limited, Leeds, we gave the sizes of their copper tubes as ranging from 24 in. bore to 0·01 in. bore. We are asked to mention that the smallest tube they exhibited was no more than 0·005 in. bore, this being the size through which air was being passed to demonstrate its soundness.

INFLUENCE OF NICKEL AND CHROMIUM UPON THE SOLUBILITY OF STEEL IN RELATION TO CORROSION.*

By Dr. W. H. HATFIELD (The Brown-Firth Research Laboratories, Sheffield).

A CAREFUL survey of the complex and diffuse problem of corrosion with regard to steels, leads to the definite conclusion that the theory which satisfactorily explains corrosion is the theory which successfully explains "chemical action." The work of the chemist during past generations, with the help of the physicist of the last few decades, is rendering the available knowledge more complete as years pass, but there is still much to learn concerning even the most familiar occurrences, amongst which the author would place the corrosion of steel.

To render knowledge more complete it is necessary to extend the data relating to the reactions of iron under varying conditions. In this paper it is proposed to discuss a series of experiments designed to give information upon the effect of alloying separately, and together, the elements chromium and nickel with iron, the carbon content being varied, and to discuss the solubility of such alloys in nitric acid, sulphuric acid, and hydrochloric acid.

The early development of nickel steels of high nickel content, the discovery by Brearley in the Brown-Firth Research Laboratories in 1913 of a 12 per cent. to 14 per cent. chromium stainless steel, and the work of German metallurgists on the quaternary rust-resisting steels, containing both chromium and nickel, have given the industrial world steels which, within a wide range of conditions successfully resist corroding influences.

Certain distinguished British scientists have recently expressed the opinion that the nickel-chromium steels of high alloy content, and the high percentage chromium steels, were worth more attention, and since the author and his staff have been working upon such steels for some years, he has secured the permission of Messrs. Thomas Firth and Sons for the presentation of the following data.

The response of steel of any given composition to varying media is naturally influenced, not only by the condition of the steel, but also by the conditions of temperature, concentration, and the degree of purity of the predominating influence in the media. Other factors also come into play, and hence to investigate completely the response of a given steel to a given medium, under various conditions, would in itself constitute an extensive and exhaustive research. It will therefore be noticed that in the following experiments the author has covered a fairly extensive field by arbitrarily choosing the conditions under which the media are allowed to react with the specimen selected.†

In this paper the experiments are confined to data derived from the effect of the three acids before mentioned —hydrochloric and sulphuric acid, which result in the liberation of hydrogen, and nitric acid, which results in the liberation of nitrous oxides. It is found that the latter is the best indication of resistance, for instance, to atmospheric oxidation. The relative resistance, however, to solution in hydrochloric and sulphuric acid has considerable industrial importance.

The General Experiments.—The steels were prepared, for the purpose of the experiments, in the form of cylinders weighing about 50 grammes, and were approximately ½ in. in diameter. They were invariably polished to a 00 emery finish (French emery-paper), it being necessary to have a uniform surface on the different samples, as the condition of the surface is an important factor in such experiments. In all cases the cylinders were totally immersed in 85 cub. cm. of the acid. Unless otherwise stated, the initial temperature was 15 deg. C., no heat being externally applied to the reaction, and no attempt was, however, made to reduce the temperature resulting from the reaction. Each test was of 24 hours' duration, and the loss stated is always in grammes per square centimetre of surface.

One difficulty which presented itself to the author lay in the fact that the influence of an element, from a corrosion point of view, is intrinsic—*i.e.*, it modifies the chemical response of the metal with which it is alloyed. It also modifies the physical condition of the steel, and this is important, since the same steel, in varying physical conditions, will give a different response to a corroding medium. Further, since different treatment for each steel will be necessary to achieve the same comparable physical conditions, whilst in others the structure is so diverse as to render this impossible, the author has contented himself, for the purpose of these particular experiments, with simply putting the steel experimented upon into the condition in which the test-pieces could be machined.

The Behaviour of Pure Metals.—It was considered that the response of the pure metals, under the conditions of the experiments, would be of interest. Cylinders of iron, nickel and chromium, submitted to the conditions of the experiments, gave the following results :—

Metal.	HCl. (Conc.)	H_2SO_4. 10 per Cent.	HNO_3. Sp. Gr. 1·20.
Iron	0·0814	0·0327	0·7165
Nickel	0·0037	0·0002	0·1546
Chromium	0·2014	0·0014	0·0006

* Abstract of a paper read at the meeting of the Iron and Steel Institute, Milan, on September 18, 1923.

† Hatfield, Faraday Symposium, ENGINEERING, vol. cxv, page 517.

It will be seen that the pure iron is soluble in all three acids, that the nickel is practically insoluble in the sulphuric acid, and that the chromium is practically insoluble in the nitric acid, specific gravity 1·20.

Carbon Steels.—Carbon steels have been shown by other investigators to respond to acids and corroding media, that response being not only affected by the carbon content, but particularly by the effect of heat treatment upon the size of structure and the arrangement of the micro-constituents. The effect of tap-water, wet and dry conditions, sea water and sulphuric acid, have been thoroughly studied in the papers referred to. Apparently minor modifications in composition may have a considerable influence upon the solubility, and this is well illustrated in the case of three commercial irons, upon which experiments were made. They were carried out upon electrolytic iron (obtained as a forged 4-in. billet), Armco iron, and English wrought iron.

As both temperature and concentration are the fundamentally important factors in determining the rapidity of solution of a steel, it was thought well, before embarking on the general experiments, which were all conducted at 15 deg. C., to take three steels and test them with varying strengths of acids at varying temperatures. The steels chosen were carbon steel, high chromium stainless steel, and 25 per cent. nickel steel.

Fig. 1. ELECTRIC OVEN USED IN THE EXPERIMENTS.

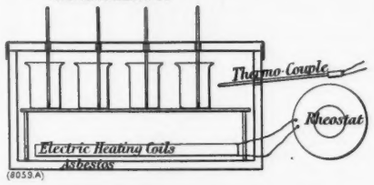


FIG. 2. FRACTURE OF HIGH-NICKEL STEEL.

With regard to the tests carried out at temperatures above the normal, it is to be recorded that an electric oven was used with a nichrome wire resistance heater, as shown in Fig. 1. The outer casing, together with the lid of the oven, were of wrought iron sheet and were lined with ⅜ in. asbestos board. Samples of steel were placed in the beakers on the grid support, as shown, the acid therein being already at the desired temperature. After the insertion of the steel samples, the lid of the oven was replaced, and the thermometers, seen in the diagram, were placed into each beaker. A thermocouple was inserted in the air space around the beakers to ascertain the temperature in that region. By the adjustment of the current, a temperature was maintained of + 2 deg. C. within the desired value, except in abnormal cases. In the exceptional case of the action of nitric acid upon a plain carbon steel, where the reaction was violent, attempts were made to keep the test cool by immersion in water during the initial stages. Such acid tests at elevated temperatures are extremely difficult to perform accurately. The heat developed by the action of the acid is a disturbing feature, but with the exception of the nitric acid experiment mentioned above, did not exceed 2 deg. C. Convection currents set up within the liquid are constantly changing the composition of the acid in contact with the metallic surface, and the rate of diffusion of the metallic salts formed is presumably not identical in all cases, added to which minute differences in the conditions of the surfaces also have an effect. The figures studied, therefore are given as being indicative of the results obtained within the possibilities of the experiment.

Strength of Acids Used.—As regards the strength of acids stated in the various tables, it should be pointed out that such figures are expressed in percentages by volume of the commercial pure acid. For the purpose, however, of making the records complete, and as a guide to other investigators working in the same field, the specific gravities and actual percentage composition by weight are given in the table annexed.

Carbon Steel.—As regards the sulphuric acid the solubility is greatest at 25 per cent., the steel becoming relatively immune with the 50 per cent. strength. As regards hydrochloric acid, the solubility increases with the strength, and such is the case with the nitric acid.

Acid Test Solutions.

—	Approximate Percentage by Volume of Commercial Pure Acid.	Specific Gravity at 15 Deg. C.	Percentage by Weight.
HCl	5	1·011	2·30
HCl	25	1·046	9·20
HCl	50	1·086	17·35
HCl	Concentrated	1·180	35·39
H_2SO_4 ..	5	1·082	11·85
H_2SO_4 ..	10	1·118	16·75
H_2SO_4 ..	25	1·297	38·97
H_2SO_4 ..	50	1·539	63·35
HNO_3 ..	9 (N/1)	1·033	6·30
HNO_3 ..	46	1·200	32·36

Stainless Steel.—Here, again, the maximum solubility occurs with the 25 per cent. sulphuric acid with decreased solubility in the 50 per cent. acid, although it is interesting to compare a solubility in the 50 per cent. acid at 80 deg. C. with that obtained with the carbon steel. The high chromium stainless steel is much less resistant under such conditions. As regards hydrochloric acid, the solubility increases with the strength of the acid. The converse is the effect with nitric acid ; whilst the steel resists specific gravity 1·20 acid up to and including 60 deg. C., definite solution takes place at 80 deg. C. In the much weaker acid of normal strength, the solubility becomes serious with higher temperatures.

Twenty-Five per Cent Nickel Steel.—Contrary to the other steels, 25 per cent. nickel steel is fairly resistant to sulphuric acid, yet the solubility may be considered to increase with the strength. In hydrochloric acid this is particularly marked, the steel being much more soluble in the 50 per cent. acid than in the 25 per cent. As regards nitric acid, the presence of the nickel has failed to make the steel less soluble than in the case of the ordinary carbon steel. With regard to all three steels, it will be noted that with the rise in temperature the solubility increases, but in varying degree. It is, of course, appreciated that a given steel should be submitted to a large number of varying strengths of acids and temperatures if the solubility curves are to be correctly drawn.

Nickel-Iron Alloys.—Much work has been done on this series. Carpenter, Hadfield and Longmuir showed that when 12 per cent. nickel was exceeded, diminished corrosion in fresh water, sea water, and 50 per cent. sulphuric acid was attained. Professor Howe also indicated the excellent resistance of 30 per cent. nickel steel to sea-water, whilst Sir Robert A. Hadfield indicated very clearly that with 50 per cent. sulphuric acid solubility was progressively decreased with increase in nickel.

Friend, West and Bentley have contributed very useful data, particularly illustrating the complexity of corrosion tests, but confirming this influence of nickel. In the author's series of steels, the results of experiments show that the carbons are fairly uniform, being between 0·16 per cent. and 0·32 per cent. The silicon does not exceed 0·41 per cent., but the manganese ranges from 0·18 per cent. to 1 per cent. This large range of manganese content would appear to be abnormal, but it was found necessary, with some of the high nickel steels, to add up to 1 per cent. of manganese to make them forge satisfactorily. In the case of one of these high nickel steels when cast experimentally without manganese, the acicular crystals separated from each other during the forging operation. An interesting photograph of the fracture is given in Fig. 2.

A survey of the results will show that solubility in 10 per cent. sulphuric acid falls off within the errors of experiments with the rise of nickel content, fairly satisfactory resistance being obtained with 30 per cent. nickel. The author's experiments would indicate that a loss of 0·0004 gramme per square centimetre of surface area practically constitutes resistance. As regards hydrochloric acid, it would appear that solubility very definitely increases up to about 12 per cent. of nickel and that after 20 per cent. is passed a progressive decrease in solubility is attained, although it is clear that none of the series can be considered resistant to this acid. As regards nitric acid, specific gravity 1·20, it is clear that the solubility is unaffected, whatever the addition of nickel to the alloys.

Iron-Carbon-Chromium Alloys.—The effect of chromium upon the solubility of steels has been studied by Monnartz, who showed that the addition of chromium increases the resistance to nitric acid, but decreases the resistance to sulphuric and hydrochloric. Friend, West and Bentley also showed that chromium favours solubility in sulphuric acid, and the same phenomenon has also been referred to in papers published by Sir Robert A. Hadfield.

Three interesting samples of stainless iron were experimented upon by the author, with the results shown in the following table :—

	Carbon, per cent.	Silicon, per cent.	Chromium, per cent.	Brinell No.	Concentrated HCl.	HNO_3 Sp. Gr. 1·20.	H_2SO_4, 10 per cent.
1	0·08	0·56	10·08	230	0·0148	nil	0·0722
2	0·07	0·73	13·26	185	0·0297	nil	0·2027
3	0·07	0·77	15·96	141	0·0416	nil	0·2763

It will be seen that here are three high chromium alloys with very low carbon content, but with silicon ranging from 0·56 per cent. to 0·77 per cent. The essential feature is that the chromium is respectively 10 per cent., 13 per cent. and 16 per cent. The acid tests clearly indicate that the effect of the chromium is to increase the solubility in both hydrochloric and sulphuric acid, whilst all three alloys were resistant to nitric acid specific gravity 1·20.

The results of acid tests on a series of nine chromium steels containing chromium up to 32·07 per cent. show that whilst the carbons vary a little yet they are within a sufficiently narrow range for a satisfactory comparison of results. The manganese content is very consistent, whilst the nickel does not exceed 0·15 per cent. The silicon also is reasonably low, in no case exceeding 0·41 per cent. The response to concentrated hydrochloric acid would certainly indicate that with a higher percentage of chromium solubility is increased. As regards resistance to 10 per cent. sulphuric acid this progressively becomes less, and is very much decreased with the high percentage chromium alloys. The results as regards nitric acid are exceedingly interesting; the 5 per cent. chromium steel appears to be more soluble in nitric than the ordinary carbon steel, but with the increase of chromium to 8·96 per cent. solubility has been decreased to such an extent that the steel is almost resistant. At 10·06 per cent. the loss in weight is only just measurable. The alloys containing a still higher percentage of chromium are completely resistant in nitric acid of this strength at ordinary temperatures.

The Influence of Nickel on the Iron-Carbon-Chromium Alloys.—The paper gives analyses of a series of steels in which several sets of steels have the same chromium content, while the nickel varied. For instance, five steels have a chromium content round about 5 per cent., and the nickel is increased by steps of 5 per cent. up to 20 per cent. The other elements are practically constant. The addition of 5 per cent. of nickel to a 5 per cent. chromium steel practically produces a steel which is almost resistant to nitric acid, whilst as regards hydrochloric acid, the addition of nickel very materially increases the resistance. As regards sulphuric acid, the gradual increase in nickel content is responsible for the production of a steel which is only very slightly soluble. Two other steels, consisting of a 10 per cent. chromium steel without nickel and one with a 5 per cent. addition of that element, show a marked increase in resistance to sulphuric acid owing to the addition of nickel. The hydrochloric acid results are apparently in the opposite direction. A survey of the figures show that the general effect of the addition of nickel to a chromium steel is to increase the resistance to nitric acid, to materially increase the resistance to sulphuric acid, and to tend to increase the resistance to hydrochloric acid. The figures also illustrate the influence of chromium upon the iron-carbon-nickel alloys, and attention is drawn to a steel (No. 5), which contains 20 per cent. nickel and 5·05 per cent. chromium. A comparison may be made of the response of this steel to the acids when compared with the 20 per cent. nickel steel. It will be found that the addition of such a comparatively small percentage of chromium has a profound effect in modifying the response of the steel to nitric acid, and in materially reducing its solubility in hydrochloric acid.

Conclusions.—The author would conclude that the metallurgy of the special steels should continue to receive every attention, since the influence of composition has by no means been exhausted. Particularly is this so as regards resistance to corroding influences. It is particularly desired to emphasise that the addition of other elements will, in limited degree, confer their properties upon steels and irons, as shown, for example by the addition of 10 per cent. to 15 per cent. of chromium stainless steels in the case of nitric acid, and the addition of 30 per cent. of nickel in the resistance of such nickel steels to sulphuric acid.

The production of quaternary steels by the addition of nickel to chromium steels not only increases their resistance to nitric acid, but also gives them increased resistance to sulphuric and hydrochloric acid.

Temperature and concentration are fundamentally important, yet these factors and others are so variable under service conditions that systematic research can hardly be expected to replace the use of tests made under such conditions as the steels may in practice be required to serve.

The author trusts that the data here given will be of interest and value to those who are pursuing work in the same field, and in conclusion he would like to record his appreciation of the assistance received from his staff in the carrying out of the experiments. To the directors of Messrs. Thomas Firth and Sons his thanks are due for their permission to publish the results of the investigations.

SOUTH AFRICAN TRADE AND INDUSTRY.—An interesting handbook of commercial information relating to the Union of South Africa, South-West Protectorate, Rhodesia, Lourenço Marques, Beira and Hinterland, has been compiled from official sources by Mr. C. W. Francis Harrison, and been recently published by Messrs. Arthurs Press, Limited, of Woodchester, Gloucestershire, at a price of 15*s.* 6*d.* post free. The title of the book is "The Trade, Industries, Productions and Resources of British South Africa and Adjacent Territories." Its author has had much experience of the work involved in the production of a book of useful statistics, as Trade Commissioner to Natal, the Union Government and the Federation of British Industries. In the 400 pages there is a wealth of information which will appeal to manufacturers and traders as well as to capitalists and others concerned with the development of Africa.

A NOTE ON COARSE CRYSTALLISATION IN MILD STEEL SHEETS.*

By Professor C. A. EDWARDS, D.Sc., and L. B. PFEIL, B.Sc., A.R.S.M. (both of University College, Swansea).

A SHORT time ago the authors had occasion to examine a rather peculiar defect which is sometimes encountered when mild steel sheets are subjected to moderately deep stamping operations. A stamping made from a sheet, $\frac{1}{16}$th of an inch thick was 7½ in. deep and 7½ in. diameter. The defect, which only becomes manifest after the process of stamping, may be described as a series of corrugations in the side walls of the dish.

The degree of corrugation increases on passing from the bottom to the top of the dish. This variation is, in all probability, due to the greater amount of cold work put upon the metal towards the top.

From a cursory visual examination of the character of the surfaces, it appeared that the immediate cause of the metal flowing into ridges was probably due to excessively large crystals in the sheet prior to stamping, and that these gave rise to what may be described as differential crystal flow during deformation. An examination of the material under the microscope very clearly demonstrated the existence of extremely large crystals in the metal. It was necessary, however, to consider the matter still further with the object of throwing more light on the problem of how these large crystals make their appearance only in a comparatively small proportion of the sheets that are used; or, in other words, why the number of stampings showing this defect is limited, even when using sheets from the same batch of steel which have gone through the rolling and annealing operations at the same time. It may be pointed out that the chemical composition of the steel was perfectly satisfactory.

Now it is well known that the crystals in ordinary mild steel possess the power of growing to a remarkable degree, if they are first subjected to a certain critical degree of cold work, and then annealed at a temperature, or range of temperature, between, say, 550 deg. and 850 deg. C. The extent of this crystal growth depends upon a number of factors which have not, as yet, been thoroughly examined; but, broadly speaking, it increases with the temperature within the above-mentioned limits. Under certain conditions the time of heating also has a material influence upon the size of the crystals obtained. These facts have been demonstrated by many investigators, and especially by Chappell, in the case of mild steel. Similar observations have been made with other metals and alloys, and the work on aluminium by Carpenter and Elam† is of special interest in this connection.

Chappell found that the critical range of stress which gives rise to extremely large crystals lies between 15 tons to 18·5 tons per square inch. In view of these facts, it was thought that the steel sheet from which the dish under consideration was made, had, during the final stages of cold rolling, been subjected to stresses between the above-mentioned limits, and that the large crystals were in consequence formed during the subsequent low temperature annealing.

There is, no doubt, an element of truth in this view, but it does not seem sufficient to account for all the facts. The most important discordant factor in this connection is that only a comparatively small proportion of the sheets made from the same cast of steel, &c., gave the trouble.

Specimens for examination under the microscope were cut from various parts of the dish, with the object of determining whether the structure of the steel was homogeneous or not. A photomicrograph taken from a specimen which was cut from the undeformed portion of the bottom of the dish, and represents the structure of the original sheet parallel with and near the surface, shows a very coarsely crystalline structure and an absence of any indication of the presence of carbon, either in the form of pearlite or cementite.

Numerous cross-sections of the sheet were cut from various parts of the dish and examined under the microscope. The structure of the complete section at a magnification of 40 diameters shows that approximately one-half of the sheet is coarsely crystalline, whilst the remaining half is almost normal. Another photograph was taken at a higher magnification; from both it was noticed that the coarsely crystalline portions contain very little, if any, indications of pearlite or carbide of iron; but that the finely crystalline parts contain an appreciable number of isolated patches of carbide.

On polishing specimens parallel with the surface of the original sheet after removing the decarbonised layer of metal, another unusual and interesting structural feature was revealed. A specimen of this kind cut from the upper, severely deformed and corrugated, part of the dish shows the deformation of the crystals further, the crystal boundaries appear as a more or less continuous clearly-defined black line. Even at the low magnification of 40 diameters the clearness of these boundaries is such as to suggest strongly the presence of a constituent other than a ferrite. Higher magnifications and further careful examination proved these to be bands of cementite running round the different crystals. This, therefore, is a remarkable instance of the formation of massive cementite of a special kind. For the present the authors do not propose to offer any explanation of how this coalescence of cementite is brought about, more especially as they intend to try and produce it intentionally, and submit their results in a further paper, at a later date.

From the foregoing observations the authors conclude that the formation of the large crystals was primarily due to the decarbonisation which occurred at some stage in the manufacture of the sheet. There are two ways in which decarbonisation of this kind may cause a substantial increase in the size of the crystals contained in the metal:—

(1) The action of removing the carbon itself may be accompanied by rapid crystal growth. The exact mechanism of this change is not known, but the fact has been clearly established by Austin.

(2) Any decrease in the carbon content of mild steel renders the metal much more sensitive to the growth of large crystals during low temperature annealing following cold-work.

The authors still felt, in spite of the views expressed above, that there might be some doubt as to whether the corrugations in the dish under consideration could definitely be associated with the presence of the large crystals. In order to meet this, they thought it might be useful intentionally to produce large crystals in sheets, and examine how they behaved when subjected to moderately severe deformation. With this in view, they experimented with strips of mild steel sheets ⅛ in. thick. These were first decarbonised, in order to facilitate crystal growth, and then submitted to varying degrees of stress followed by annealing at about 850 deg. C. In other words, the method adopted was similar to that used by Carpenter and Elam in their classical work on aluminium. In this way many very large crystals were obtained extending right through the sheet. A photograph, natural size, of another specimen which has been elongated 25 per cent. in a tensile testing machine, show the average size of the crystal to be about $\frac{3}{16}$ in. The irregularity of the surface after deformation was very marked, and in all essentials was remarkably similar to that on the dish.

In conclusion, the authors venture to hope that the observations recorded in this short paper will be of interest to those engaged in the manufacture and treatment of mild steel sheets.

* Abstract of a paper contributed to the meeting of the Iron and Steel Institute, Milan, September, 1923.

† ENGINEERING, vol. cxv, pages 579, 612, 636.

CATALOGUES.

Well Pumps.—Messrs. Sulzer Brothers, Winterthur, have sent from their London Office, 31, Bedford Square, W.C., a catalogue of the centrifugal pump which they recommend for borehole wells.

Machine Tools.—Messrs. Smart and Brown, Erith, Kent, have issued catalogues of a lathe attachment for milling, gear-cutting and other work. The attachment is shown mounted on an 8-in. centre lathe, and is capable of a great variety of heavy and accurate machining.

Electrical Machines.—The British Thomson-Houston Co., Limited, Rugby, have sent us some of the recent issues of their carefully prepared lists and catalogues relating to induction motors, and oil immersed star-delta starting switches for squirrel-cage induction motors.

Die Casting Machine.—A small machine suitable for producing die castings up to 5 lb. in weight and capable of being operated without special skill, is described in a catalogue received from the selling agents, Messrs. Charles Churchill and Co., Limited, 9, Leonard-street, London, E.C.2.

Aluminium.—A catalogue of extruded sections and of matting (*i.e.*, sheets with footgrip surfaces) in aluminium and of smooth sheets in aluminium and copper is to hand from British Insulated and Helsby Cables, Limited, who manufacture these materials at their works in Prescot, Lancs.

Grinding Attachments.—Leaf catalogues illustrating electric grinding spindles for attachment to the lathe slide rest, an electric drilling machine for breast pressure or attachment to a bench pillar, and a neat box fitted with motor and grinding spindle, are to hand from Messrs. Ibbetson and Co., 57, Chancery-lane, London, W.C.

Diathermy Apparatus.—An apparatus for the application of electrical current to raise the temperature of the body in the treatment of disease by a process known as diathermy, is described very fully in a revised edition of a special catalogue issued by Messrs. Watson and Sons, Limited, Parker House, Kingsway, London, W.C.

Shaft Couplings.—A catalogue of interchangeable flexible couplings of Thomson-Houston design for shafts of all sizes from ½ in. to 5½ in. in diameter is to hand from Messrs. R. Hunt and Co., Limited, Earls Colne, Essex. Various types of pulleys and housings for bearings are also illustrated in a separate leaf catalogue.

Spur Gears.—Two catalogues from Laminated Gears Limited, Sedgley Road, Owlerton, Sheffield, illustrate the firm's reduction gears applied to line shafts in textile factories and to the direct drive of machine tools, pumps, printing machines, &c. The gear wheels and pinions consist of plates assembled on a hub so that the teeth on alternate plates are staggered. Silent running, long life, improved lubrication and the reduction of back lash are claimed for this method of construction.

Aluminium Bus-Bars.—The use of aluminium in place of copper for bus-bars and connections is discussed clearly and fully, with due consideration of all the necessary technical, practical and financial points in a 20-page catalogue issued by the British Aluminium Company, Limited, 109, Queen Victoria-street, London, E.C. The joints, bends, coils, &c., are illustrated in detail, and tables are given of dimensions and capacities for aluminium flat bars and rods, comparative current carrying capacity of copper and aluminium bus-bars, and other matters. The cost of aluminium is put at 25 per cent. less than that of copper for any given length and resistance of bar.

THE DESIGN OF ROTATING DISCS.

By G. ARROWSMITH, M.Sc.(Tech.).

THE complete evaluation of the stresses in a rotating disc is of necessity a somewhat tedious process; but in view of the present-day tendency towards turbine units of large output running at relatively high speeds of rotation, it is a problem which has carefully to be considered. Since the grade of steel commercially obtainable for the manufacture of discs has a fairly definite maximum tensile strength it is essential that we so proportion our discs that the disposition of stresses is such as to give the highest possible factor of safety consistent with the qualities of material that are procurable.

Definite solutions of the differential equations of stress have only been obtained for a few particular cases where the radius and the axial thickness of a disc bear a definite mathematical relationship. Thus Professor Stodola obtained a solution for the case of discs of hyperbolic section:—

Where x = any radius of disc.
y = corresponding thickness.
Then:

$$y\,x^a = \text{Constant}.$$

Mr. H. M. Martin showed that for discs of the above type it is possible to construct a series of standard curves corresponding to various values of a, and by the use of these the amount of work involved was greatly reduced. Both of these methods were, however, only applicable to discs whose profile conformed throughout to the hyperbolic law. In actual practice it is in many cases impracticable to employ discs which conform even approximately to this contour, and a further point of even greater importance is that a disc of hyperbolic form does not in many cases produce the best distribution of stresses.

In the method here outlined the mathematical accuracy of the original solution of Stodola has been maintained, but the equations have been so transposed that discs of any reasonable contour can be treated. Fig. 1 shows the practical design of a simple turbine disc, the sides having straight line tapers. If this disc be now considered to consist of a series of consecutive rings, 1. 2. 3. &c., although the complete disc by no means conforms to a true hyperbolic section, by making the radial steps of moderate dimensions, the error involved in assuming any particular section to form a portion of an "a" disc is negligible. Thus in Fig. 1 the various sections indicated have a values as follows:—

Section	1	2	3	4	5	6	7	8
a =	0·62	0·91	1·27	1·6	0·52	0·72	1·0	1·44

The method adopted consists of a simple means of co-ordinating the various sections and so obtaining a complete solution of the disc. Further it will be shown that it is possible to reverse the process and that after drawing down a stress curve to suit any particular requirements the disc shape necessary to meet the case can be obtained.

The distribution of stresses in a disc of hyperbolic section is given by the following equations:—

$$\sigma_r = \frac{E}{1-\nu^2}\left[\beta_1(\psi_1+\nu)x^{\psi_1-1} + \beta_2(\psi_2+\nu)x^{\psi_2-1} - \frac{K(3+\nu)}{[8-(3+\nu)a]}x^2\right] \quad . \quad . \quad \text{(i)}$$

$$\sigma_t = \frac{E}{1-\nu^2}\left[\beta_1(1+\psi_1\nu)x^{\psi_1-1} + \beta_2(1+\psi_2\nu)x^{\psi_2-1} - \frac{K(1+3\nu)}{[8-(3+\nu)a]}x^2\right] \quad . \quad \text{(ii)}$$

$$\psi_1 = \frac{a}{2} + \sqrt{\frac{a^2}{4} + a\nu + 1}$$

$$\psi_2 = \frac{a}{2} - \sqrt{\frac{a^2}{4} + a\nu + 1}$$

σ_r = Radial Stress.
σ_t = Tangential stress.
E = Elastic modulus.
ν = Poisson's ratio (0·3 for steel).
x = Radius in inches.

$$K = \frac{w\,\omega^2}{12\,g} = 8{\cdot}05\left(\frac{R\,P\,M}{1{,}000}\right)^2 \text{ for steel discs.}$$

(It is to be noted that K x^2 gives the hoop stress in an unsupported steel ring of radius x.)

β_1 and β_2 are constants which depend upon the conditions of loading at the inner and outer edges of the disc.

If we write in equations (i) and (ii) arbitrary values σ_{r_0} and σ_{t_0} at any definite radius x_0, the values of β_1 and β_2 can at once be determined, and corresponding stress at any other radius x can then be found.* Adopting this procedure, equations (i) and (ii) can then be thrown into the simple forms:—

$$\sigma_r = A\,\sigma_{r_0} + B\,\sigma_{t_0} - C\,K\,x_0^2 \quad . \quad . \quad \text{(iii)}$$

$$\sigma_t = E\,\sigma_{r_0} + F\,\sigma_{t_0} - G\,K\,x_0^2 \quad . \quad . \quad \text{(iv)}$$

From these equations it will be seen that at any point both the radial and tangential stresses comprise a definite proportion of the radial and tangential stresses at the known point, less a factor depending upon the hoop stress due to the running speed. If we put $r = \frac{x}{x_0}$, then the values of the various constants are as follows:—

$$A = \frac{\psi_1 r^{\psi_1-1} - \psi_2 r^{\psi_2-1}}{\psi_1-\psi_2}$$

$$B = \frac{r^{\psi_1-1} - r^{\psi_2-1}}{\psi_1-\psi_2}$$

$$C = \frac{\{(3+\nu)(\psi_1-\psi_2)r^2 - (\psi_1+\nu)(3-\psi_2)r^{\psi_1-1} + (\psi_2+\nu)(3-\psi_1)r^{\psi_2-1}\}}{(\psi_1-\psi_2)[8-(3+\nu)a]}$$

$$E = \frac{(1+a\nu)(r^{\psi_1-1} - r^{\psi_2-1})}{\psi_1-\psi_2}$$

$$F = \frac{\psi_1 r^{\psi_2-1} - \psi_2 r^{\psi_1-1}}{\psi_1-\psi_2}$$

$$G = \frac{\{(1+3\nu)(\psi_1-\psi_2)r^2 - (1+\nu\psi_1)(3-\psi_2)r^{\psi_1-1} + (1+\nu\psi_2)(3-\psi_1)r^{\psi_2-1}\}}{(\psi_1-\psi_2)[8-(3+\nu)a]}$$

* The insertion of arbitrary stresses in Stodola's equations appears to have been first suggested by H. Holzer. *Zeitschrift Turbinenwesen*, September 20, 1913.

In the expressions for A, B, C, E, F and G there are two variables, r and a, and the constants have been evaluated for values of a varying from 0 to 3, and values of r from 1·2 to 1·02. These results are given in Tables I, II, III and IV, on page 418, but as in dealing with actual examples it is much simpler to base the calculations on the ratio $\frac{y_0}{y} = r^a = \rho$ the final results given in the tables are shown as corresponding to definite values of ρ.

In calculating the stresses of any given disc it is most convenient to commence at the bore of the hub and to work outwards, since at this point the radial stress may be taken as zero. Even in the case of a disc shrunk on to the shaft, when the disc is brought up to speed, the effect of the shrinkage practically disappears.

For most cases we may employ Table I, where the ratio of succeeding steps is 1·2, commencing at the inner radius a series of radial dimensions are written down, each having a uniform increment of 20 per cent. The spacing of the steps is thus a simple geometric progression, the distance between successive steps being proportional to their distance from the centre of the disc. This spacing is quite satisfactory, since it gives the closest pitching at the points where the stress curves have their steepest gradients. Having ascertained the radial steps the corresponding disc thicknesses can be written down, and thence the ratio $\frac{y_0}{y} = \rho$ for each step. It is now only necessary to read from Table I the constants corresponding to the required values of ρ.

As an example, the maximum load-carrying capacity of the disc shown in Fig. 2 has been calculated for a speed of 3,000 r.p.m. The whole of the working is given in Table V. The explanation of the various columns is as follows:—

(1) The radius at which the stress is required.

(2) The ratio of succeeding radii, in this case taken as 1·2, except at the last step where $r = 1{\cdot}02$, was taken to bring the value of x to the outside radius of 22 in.

(3) The thickness taken from the disc to correspond to radius x.

(4) The ratio ρ for succeeding values of y.

(5) The value of K x_0^2 required in columns 7 and 10. In this case for a speed of 3,000 r.p.m.

$$K = 8{\cdot}05\left(\frac{3{,}000}{1{,}000}\right)^2 = 72{\cdot}45.$$

The suffix o in each case indicates the value from the preceding step so that at $x = 6$, K $x_0^2 = 72{\cdot}45 \times 5^2 = 1{,}810$.

(6) Constants taken from table corresponding to the correct value of r and ρ.

(7) The three factors in equation (iii).

(8) The sum of the factors giving the radial stress at the new radius.

(9) Constants from tables.

(10) The three factors in equation (iv).

(11) The sum of these factors giving the new tangential stress.

The values in columns 1, 2, 3 4, and 5 can be filled in completely, from the particulars of the disc. If now we decide upon a maximum tangential stress of 28,000 lb. per square inch at the bore of the disc ($x = 5$ in.), this is filled in on the first line, the corresponding radial stress being zero. Using these values the stresses at the next step can be found, and repeating the process throughout the disc the complete solution is obtained. The stress curves are shown plotted in Fig. 2. It will be seen that at the disc periphery a radial stress of 12,090 lb. per square inch is obtained, and providing the loading of the disc due to the centrifugal force of blading and disc rim does not exceed this figure, we know that the maximum disc stress at the bore is within the safe limit of 28,000 lb. per square inch. This in most cases is all that is necessary, but if the exact stress curves are required to correspond to some other radial rim stress, these can readily be obtained by adopting the principle set out by Mr. Martin in connection with his standard disc curves. He shows that in any disc it is possible to divide the stress at any point into two portions (1) that due to the centrifugal force acting on the disc itself and (2) the stress induced due to the applied centrifugal loading at the rim.

These stresses can be calculated separately, the

Fig. 1.

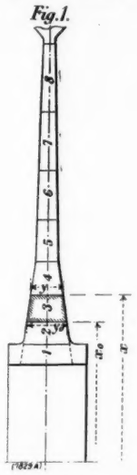
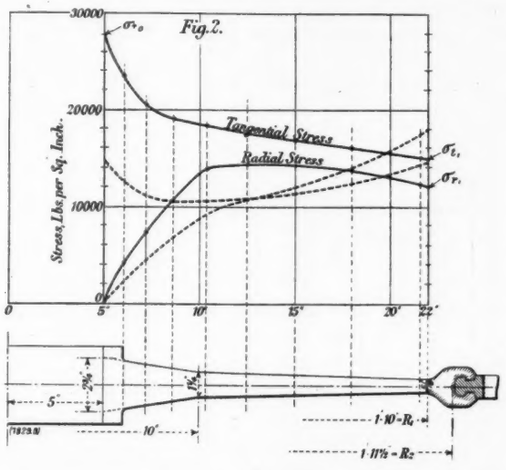



Fig. 2.